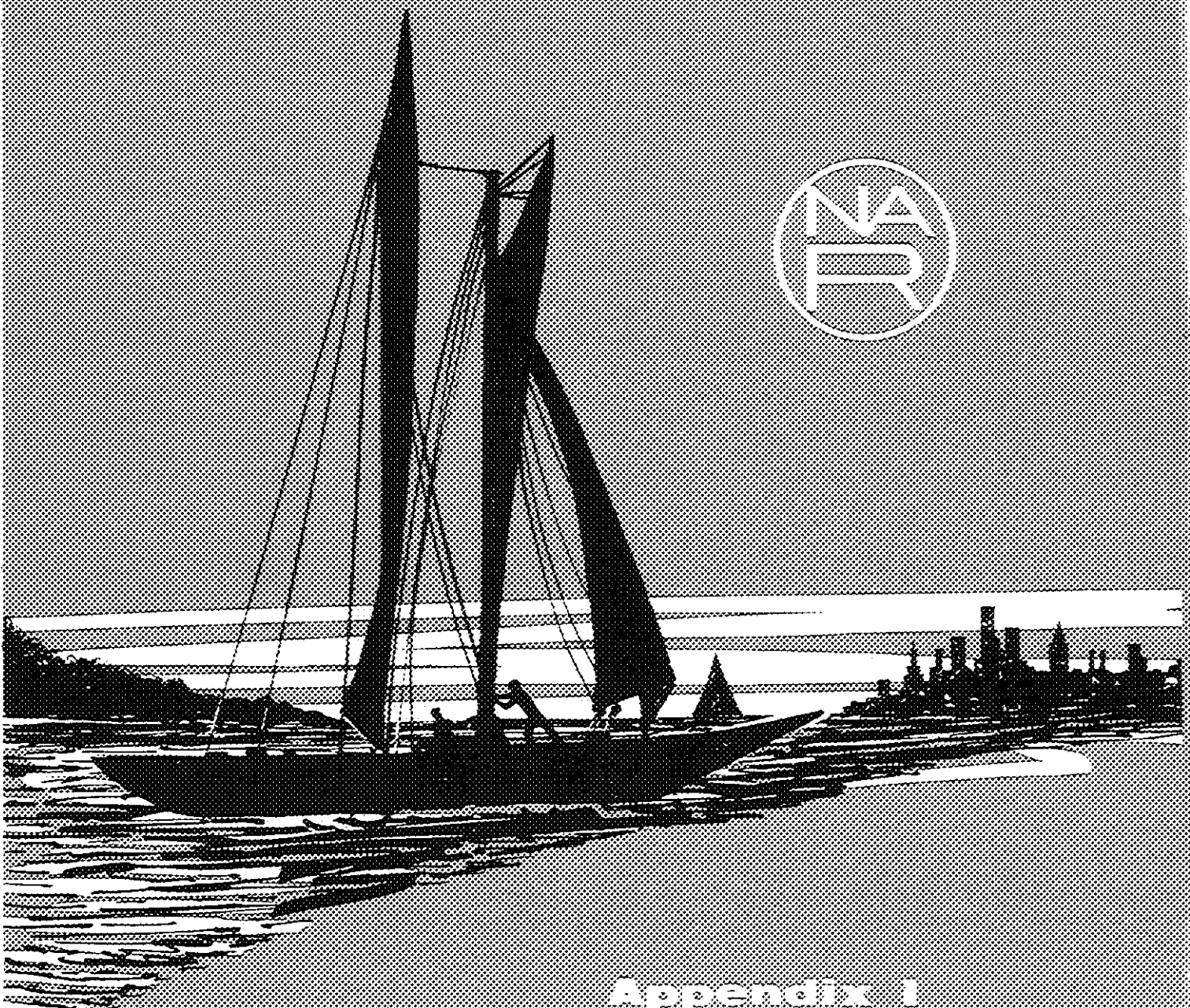
North Atlantic Regional Water Resources Study



Appendix 1
Irrigation

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY COORDINATING COMMITTEE
MAY 1972

The North Atlantic Regional Water Resources (NAR) Study examined a wide variety of water and related land resources, needs and devices in formulating a broad, coordinated program to guide future resource development and management in the North Atlantic Region. The Study was authorized by the 1965 Water Resources Planning Act (PL 89-80) and the 1965 Flood Control Act (PL 89-298), and carried out under guidelines set by the Water Resources Council.

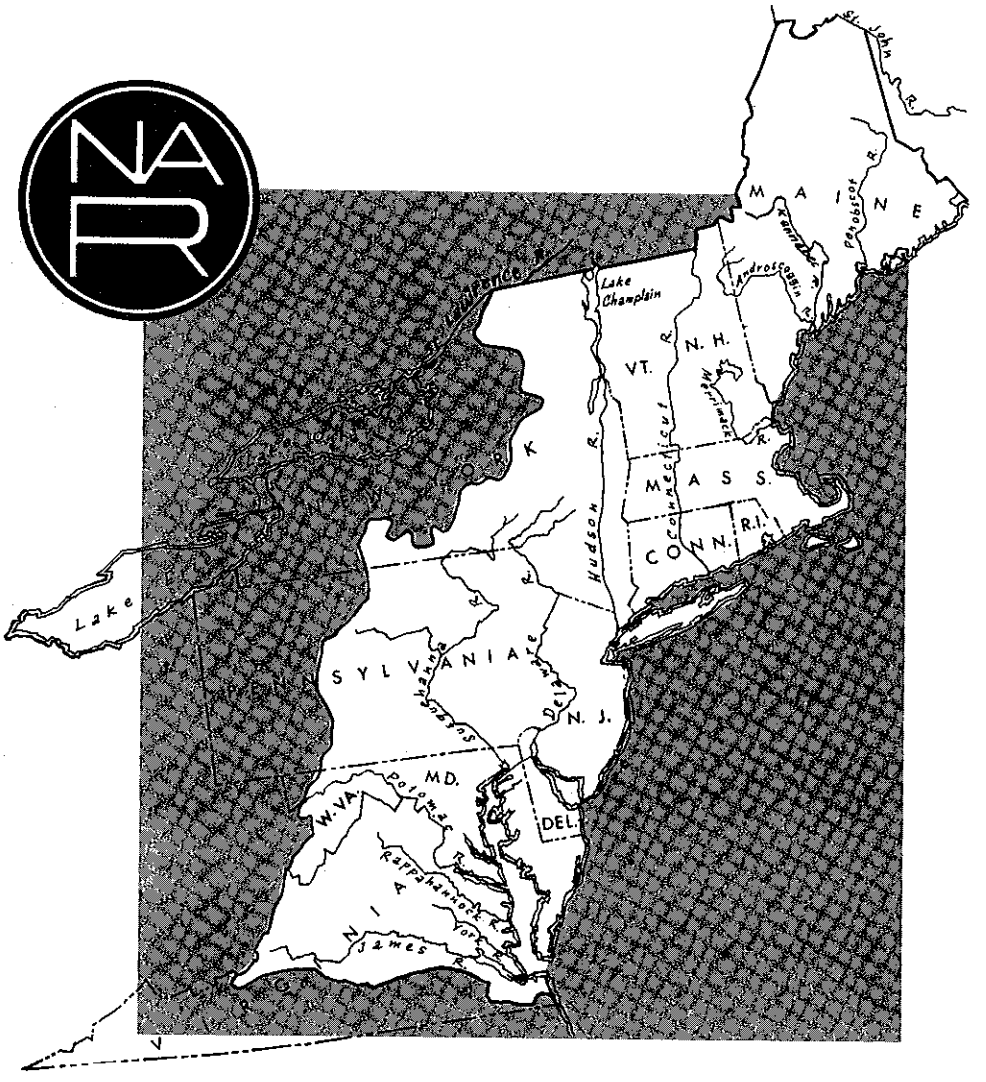
The recommended program and alternatives developed for the North Atlantic Region were prepared under the direction of the NAR Study Coordinating Committee, a partnership of resource planners representing some 25 Federal, regional and State agencies. The NAR Study Report presents this program and the alternatives as a framework for future action based on a planning period running through 2020, with bench mark planning years of 1980 and 2000.

The planning partners focused on three major objectives -- National Income, Regional Development and Environmental Quality -- in developing and documenting the information which decision-makers will need for managing water and related land resources in the interest of the people of the North Atlantic Region.

In addition to the NAR Study Main Report and Annexes, there are the following 22 Appendices:

A. History of Study
B. Economic Base
C. Climate, Meteorology and Hydrology
D. Geology and Ground Water
E. Flood Damage Reduction and Water Management for Major Rivers and Coastal Areas
F. Upstream Flood Prevention and Water Management
G. Land Use and Management
H. Minerals
I. Irrigation
J. Land Drainage
K. Navigation
L. Water Quality and Pollution
M. Outdoor Recreation
N. Visual and Cultural Environment
O. Fish and Wildlife
P. Power
Q. Erosion and Sedimentation
R. Water Supply
S. Legal and Institutional Environment
T. Plan Formulation
U. Coastal and Estuarine Areas
V. Health Aspects

Appendix I
Irrigation



Prepared by

Economic Research Service, Forest Service
and Soil Conservation Service
United States Department of Agriculture

for the

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY
COORDINATING COMMITTEE

TABLE OF CONTENTS

III - REGIONAL SUMMARY

IV - SUBREGIONAL SUMMARIES

LIST OF TABLES

Tables appear in numerical order after the Bibliography.

LIST OF FIGURES

Figures are in numerical order after the Tables.

LIST OF EXHIBITS

I - SYLLABUS

Irrigation in the North Atlantic Region (NAR) has increased substantially since the end of World War II. After the War the development of aluminum pipe and more efficient distribution systems lowered costs sufficiently to make irrigation economical to more farmers in the Northeast than ever before. Irrigated acres in the NAR increased from 85,800 in 1949 to 282,300 in 1964. The largest increase was from 1949 to 1954. By the year 2020 it is expected that there will be about 480,100 acres of agricultural land being irrigated.

For the purpose of this study land is considered irrigable if irrigable soil is available for crop use and if there is economical access to a source of water. The acreage of irrigable soil in crop and pasture is much greater than the projections of irrigated land. Thus, it is assumed that there will be sufficient irrigable land to meet the projections of irrigated land.

The types of crops most extensively irrigated in the Region are potatoes, vegetables, fruits, tobacco, berries and nursery crops. It is expected that a larger percentage of these high value crops will be irrigated in future years. In addition to satisfying plant moisture requirements, irrigation will be utilized increasingly for quality improvement, more efficient use of fertilizer, greater plant population, and frost protection.

The source of agricultural irrigation water is about evenly divided between surface and ground water sources with the trend appearing to favor surface water sources. More than 60 percent of the irrigated acres is irrigated through the use of constructed reservoirs. The predominant method of water distribution is by portable pipe and sprinkler systems.

Gross seasonal agricultural irrigation water requirements in the Region for 1980, 2000 and 2020 are 460,600 acre-feet, 525,200 acre-feet and 520,900 acre-feet respectively. About 90 percent of the seasonal irrigation water requirements is needed from June through August.

Irrigation of industrial and institutional lawns and golf courses was considered in this study. Seasonal irrigation water requirements for these nonagricultural uses in the Region for 1980, 2000 and 2020 are 301,100 acre-feet, 487,600 acre-feet and 717,400 acre-feet respectively. About 86 percent of the nonagricultural irrigation water requirement is for golf courses.

Exhibit 2 at the end of this appendix shows in tabular form the agricultural and nonagricultural irrigation demands by Area for the time frame years for the National Efficiency (NE), Regional Development (RD), and Environmental Quality (EQ) objectives.

The irrigation needs will be compared with other water needs. The allocation of water will be based on availability and priorities. It appears that irrigation needs can be fulfilled with the ultimate determination being made in plan formulation.

Detailed irrigation studies should be considered in Areas 1, 9, 13, 15, 16 and 18[1/] as part of future detailed comprehensive river basin studies. This recommendation was based upon the quantity of irrigation water needed, the percent of total cropland that will be irrigated, and the water requirement per square mile of drainage area.

1/ See Figure I-1 for Area location.

II - INTRODUCTION

PURPOSE AND SCOPE

Purpose. The purpose of this appendix is to provide an appraisal of irrigation water needs in the NAR. Although irrigation needs are not as critical in this region as in more arid regions, it is realized that irrigation water to satisfy plant moisture requirements is a major water consumer even during years with normal amounts of precipitation during the growing season.

Scope. The nature of the appraisal is necessarily broad because of the size and diversity of the NAR. The general data and methodology used could provide the basis of rationale for future local planning studies; however, their literal application could lead to erroneous conclusions.

This appendix presents the past and present irrigated land in farms, including the present cropping pattern on irrigated land. Future irrigation water needs are based on projections of irrigated acreages for the target years 1980, 2000 and 2020. Water requirements and responses as analyzed in this report are based on soils suitable for irrigation under the highest levels of farm management.

The appendix also presents future irrigation water needs for industrial and institutional lawns, and golf courses. The water needs are based on acreage projections for these nonagricultural uses.

HISTORY

Past Trends. Irrigation has been practiced in the NAR for as long as crops have been cultivated. Phelps (1) indicates that as early as 1796 water was conducted through ditches and wooden pipes and applied to fields by furrows. Before World War II, however, irrigation in the NAR was not very important. The region is normally blessed with a relative abundance of evenly distributed rainfall. Crop failures have been rare but reduced yields have not been uncommon. Following World War II, with the advent of light weight aluminum pipe and more efficient pumping systems, irrigation costs were lowered significantly, especially maintenance and labor. Other technological improvements including "quick coupling" devices, and improved notors and fuels increased the efficiency of irrigation systems. This increase in efficiency is especially important in the NAR where irrigation is used as a supplement to natural moisture rather than as the only source of moisture for a crop.

Improved equipment coupled with high product prices in the postwar years resulted in more favorable returns attributed to irrigation. During the dry growing seasons the net returns to irrigation have been reported to be quite high. Returns to irrigation are not as dramatic in many growing seasons due to the relatively high seasonal rainfall.

Insurance against reduced yields due to drought condition is not the only consideration for using irrigation on many of the high value crops grown in the Region. Irrigation also significantly increases the quality of tree fruits as well as vegetable crops. The use of irrigation systems for frost protection is becoming indispensible to tree fruit, berry and vegetable production. Irrigation has also enabled the farmer to obtain a greater response from fertilizer through heavier applications

(1) Numerals in parentheses refer to the bibliography at the end of the Appendix.

and more efficient plant use. The sprinkler system has also provided the farmer with an efficient method of applying liquid fertilizer.

Irrigated Land. In the 1964 Agricultural Census there were 282,300 acres of irrigated land in farms in the NAR (Table I-1). This acreage represents less than two percent of the Region's Cropland (Table I-2) and less than one percent of the total irrigable soil (Table I-3). Thus, it is evident that only a very small portion of the cropland in farms is irrigated. However, since irrigation is practiced primarily on high value crops, the irrigated acres become more significant when considering total farm production.

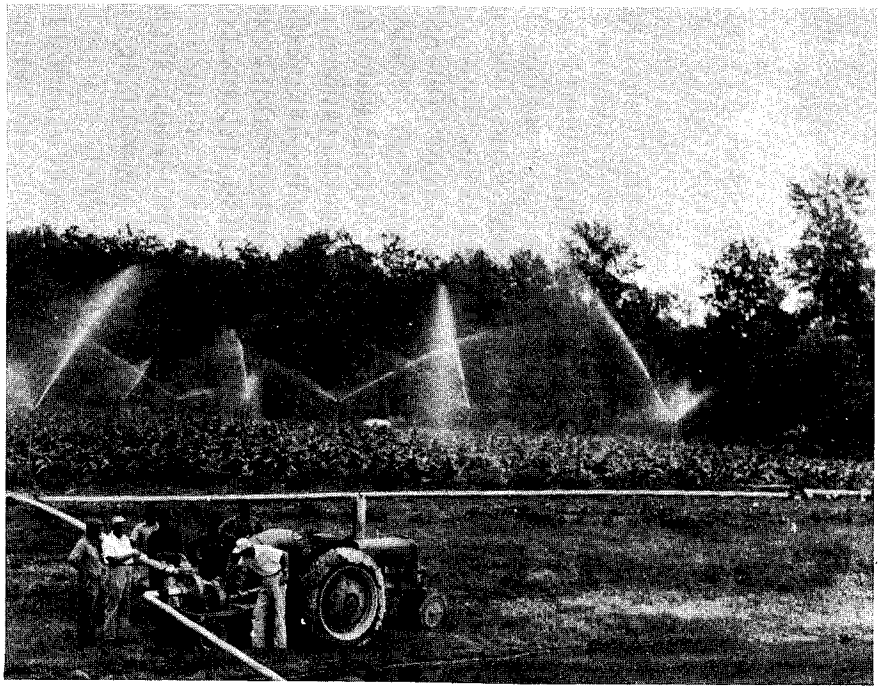
Figure I-2 to I-7 indicate the disposition of the irrigated land in the Region. In general, much of the irrigation is concentrated in the Lower Connecticut Basin, Long Island, New Jersey and Delaware portions of the Region. Irrigation has developed in these areas primarily because of market locations, soil conditions, topography, climate, and water availability.

The acreage and percentage distribution of irrigated crops in 1964 in the NAR are presented in Table I-4, Table I-5 and Figure I-8, respectively. More than 23 percent of the irrigated acres of the Region is in potatoes, and all vegetables account for 42.3 percent. Of the vegetables, sweet corn, snap beans and tomatoes are the crops most commonly irrigated. Berries are grown on 7.8 percent of the irrigated acreage with nearly 67 percent of these being cranberries irrigated in Areas 9, 15 and 16. Tobacco is important in the Connecticut Basin, but represents only 3.3 percent of the Region's irrigated land. Corn for grain is a rather insignificant irrigated crop in the Region, accounting for only 1.4 percent of the irrigated land.

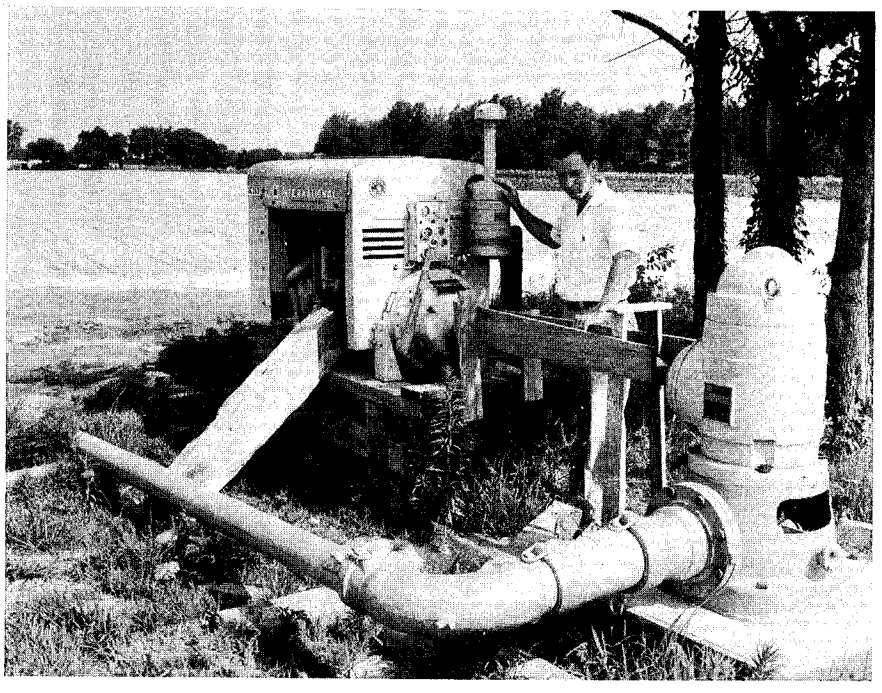
Rates of Water Usage. A general rule of thumb used by many farmers is that of applying one inch of water per week when there is no rainfall for all soils and crops. Many times too much water is applied because the farmer did not consider the available moisture in the soil and the growth stage of the plant. At other times the practice of applying one inch per week is far short of plant needs. This is especially true during drought periods of long duration.

Enough water should be applied per irrigation to fill the plant root zone to field capacity. Indications are that the farmers are not applying sufficient water for maximum yields. For example, in Area 15 for the 1955 crop season the total water application was about one half the computed requirements.(2)

Sources of Supply. Irrigation water coming from surface water sources in 1950, 1955 and 1960 was about 14 percent(3), 66 percent(4), and 50 percent (Table I-6) respectively. The trend is not clear-cut, but indications are that a greater percentage of irrigation water is being taken from surface water sources. Of the acres being irrigated in 1960, about 64 percent were irrigated through the use of constructed reservoirs.



Farm pond is reservoir for water used to irrigate tobacco crop.



Deep well irrigation pump is used to supply water for truck crops.

METHODOLOGY AND ASSUMPTIONS

Establish Study Areas. The material in this appendix is presented according to the six Subregions and 21 Areas delineated by the Coordinating Committee. The 21 Areas are grouped into the six Subregions and coincide with hydrologic units as shown in Figure I-1.

Existing Data. Wherever possible use was made of existing data, records and reports. All tables containing secondary data by Subregion and Area were assembled by the summation of county data. The counties were grouped to closely approximate each of the 21 Areas.

Cropland Projections. The NAR is unique in that over 25 percent of the nation's population lives on approximately five percent of the nation's land area. The problem of meeting the demand for food from within in the NAR is even further increased when we consider that only 3.6 percent of the nation's cropland is located in the Region.

It is evident that the demand for agricultural products in the Region is outrunning the supply. Figure I-9 clearly shows that only in poultry and potatoes does NAR production exceed NAR product requirements. The other needs are supplied to the Region from surpluses produced in other parts of the country. Normally, the projection procedure involves relating the future agricultural production and land use to the demands for food and fiber from within the Region. However, since only a small portion of total Regional consumption is supplied from within, it becomes difficult to relate future production with demand. Thus, for this appendix it was assumed that food and fiber demands were not a limiting factor on future production.

In preparing projections of irrigated acreages for the NAR, the following assumptions were considered:

> The farmers of the Region will make no serious future attempt to overcome the intraregional production deficits and, in fact, in future years the Region will produce a smaller portion of its food and fiber requirements than at present.
> All vegetables, fruits, and potatoes will be irrigated by 2020 in the NAR. This assumption also includes tobacco in the Connecticut Basin and cranberries in Massachusetts and New Jersey.
> There will be no shortage of water to limit irrigation.
> Total nonirrigated cropland acreages will continue to decline but at a slower rate in future years.

With the above assumptions, irrigated acreages in future years are associated with the total acreage[1/] of vegetables, fruits and potatoes. The task now is to project total acreages of these crops. An exponential curve provides the best fit to the historical production data for the above crops. This curve assumes that the acreages of these crops will continue to decrease as in the past but the rate of change will be slower.

1/ Includes tobacco and cranberries in Areas 8 and 9 and cranberries in Areas 15 and 16.

The exponential curve was fitted to census acreages[1/] of vegetables, fruits, and potatoes for 1949, 1954, 1959 and 1964, for each Area in the NAR. The curve was extended by the exponential equation to 2020. Table I-7 shows the projected total acreages of these specialized crops.

Recall the earlier assumption that all of these crops would be irrigated by 2020. The year in which all of the vegetables, fruits and potatoes were assumed to be irrigated was varied by Areas according to the percentage of these crops that were irrigated in 1964. In other words, if a large percentage of vegetables, fruits, and potatoes were irrigated in 1964, then these crops would be completely irrigated in an earlier year than in an Area where a lower percent was irrigated in 1964. Now it is possible to pick a year on the curve where all of these high value crops will be irrigated. After the 100 percent irrigation point was obtained, the curve was allowed to decline only where substantial urban and industrial development is expected to continue to encroach upon agricultural land. Example: Area 13 - Long Island.

Once the basic projections were made for irrigation of vegetables, fruits and potatoes, a percentage was added to account for irrigation of other crops (nurseries, field crops, forage, etc.).

The projections (Table I-8) were tempered by judgment and opinion of agricultural experts who are knowledgeable about certain specific areas in question.

Irrigable Land. The question arises as to whether there will be sufficient irrigable land to meet the projections for irrigated land. For the purpose of this study, land will be considered irrigable if irrigable soil is available for crop use and if there is economical access to a source of water.

It was assumed that the amount of irrigable soil was equal to the sum of acreages of SCS Land Capability Classes I, II, and III. A soil is placed into a Land Capability Class based on those properties that limit or restrict the use or determine the ability of land to produce continuously without deterioration. There are eight Land Capability Classes with the limitations in use or risks of soil damage becoming progressively greater from Class I to Class VIII. Soils in the first four classes are capable under good management of producing the common cultivated crops. Class IV was not considered irrigable for this study because it has very severe limitations for use as cultivated land. Some soils in Classes VI and VII are capable of producing specialized crops but it was assumed that the amounts of soil that would be irrigated in these two classes are negligible.

1/ Includes tobacco and cranberries in Areas 8 and 9 and Cranberries in Areas 15 and 16.

If the acreage of irrigable soil in crop and pasture (Table I-3) is much greater than the projections of irrigated land (Table I-8) it will be assumed that there is sufficient irrigable land to meet the projections of irrigated land. That is, irrigable soil will be available for crop use with economical access to a source of water so that it can be classified as irrigable land.

The total column in Table I-3 includes all irrigable soil. Major land use adjustments will be considered if the acreage of irrigable soil in crop and pasture is not much greater than the projections of irrigated land, that is, the conversion of forest and woodland, idle land and/or other land to irrigated cropland.

Irrigation Water Requirements. Up to this point the discussion has been involved with the methodology and assumptions for projecting irrigated land and whether there will be sufficient irrigable land to meet the projected irrigated acreages. The next step is the determination of irrigation water requirements. A computer program was developed by the SCS Engineering & Watershed Planning Unit in Upper Darby, Pennsylvania to determine the net and gross irrigation water requirements. The irrigation water requirement is equal to consumptive use minus effective rainfall minus carryover moisture.

Many factors operate singly or in combinations to influence the amounts of irrigation water consumed by plants. The most important are climate, carryover moisture, rainfall and plant growth characteristics.

A modified Blaney-Criddle Method was used to compute the monthly and seasonal consumptive use requirements for the crops listed in Table I-9. Consumptive use includes the water transpired by the plants and water evaporated from the adjacent soil, plus the evaporation of the water intercepted by the plant foliage. It is assumed in this report that consumptive use is the amount of water that a crop would require when the soil moisture is not limited.

Input data for the computer program included the following: latitude, average annual rainfall, average monthly temperature, average monthly precipitation, planting date, harvesting date, carryover moisture, seasonal crop coefficients, crop growth stage coefficient, percent chance rainfall, and net depth of application.

The average monthly temperature was compiled from U. S. Weather Bureau information. Using the latitude, the monthly percentage of daytime hours of the year for each month was obtained from a table in TR-21.(5) A monthly consumptive-use factor was computed using the above information. A consumptive-use coefficient for each month was computed using a climatic coefficient and a coefficient reflecting the growth stage of the crop. Values of monthly and seasonal consumptive use for a plant were computed by combining the consumptive use factor and the consumptive use coefficient.

Effective rainfall supplies a portion of the consumptive use by plants. It is that part of the precipitation during the growing period which is not lost to deep percolation below the root zone or to surface runoff. The average monthly effective rainfall is obtained from a figure in TR-21, using the following three factors: average monthly rainfall, the average monthly consumptive use of the plant, and the net depth of water application per irrigation. The net depth of water application per irrigation is the net amount of moisture to be replaced at each irrigation. It is the amount of moisture that the soil can hold between field capacity and the starting moisture level.

The 90 percent chance monthly effective rainfall is obtained by multiplying the average monthly effective rainfall by a factor from a table in TR-21. For a greater degree of accuracy, a frequency distribution of growing-season rainfall can be plotted using at least 25 years of annual growing season values from U. S. Weather Bureau Records.

The following assumptions were used in determining the total irrigation water requirements.

The carryover moisture is equal to 50 percent of the available moisture capacity. The available moisture capacity is the amount of water within the effective root zone that the soil will hold between field capacity and the permanent wilting point.

Winter precipitation is sufficient to bring the soil moisture within the root zone up to field capacity.

Net depth of irrigation application is equal to 50 percent of available moisture capacity.

The field application efficiency is 70 percent. Application losses include evaporation, deep percolation, and surface runoff. The extent of such losses depends on intake characteristics of soils, topography, climate, net depth of application, unequal application distribution, irrigation methods, adequacy of system design and installation, and skill of the irrigator.

Irrigation root zone depths for the different crops and the associated available moisture for a particular soil were taken from Soil Conservation Service Irrigation Guides for the States in the NAR.

The net irrigation requirement is the consumptive use minus the sum of the effective rainfall and the carryover moisture stored in the soil at the beginning of the growing season. The gross irrigation requirement is the net requirement divided by the field application efficiency. The gross irrigation requirements were based on general soils and climatic conditions and will vary from specific locations.

Water Quality. The quality of water in upstream areas is for the most part adequate for irrigation.

Irrigation water near coastal areas may be somewhat brackish. Brackish water is usable for crop production when it is a tenth to an eighth as salty as seawater. (6) Crops vary as to their salt tolerance, e.g., tomatoes are more tolerant to salinity than are apples.

Salts may accumulate in soils of humid regions if brackish water is used for irrigation. Tests in Virginia show that normal winter rainfall will usually leach from the soil most of the salt which may have accumulated during the growing season. Good drainage is essential in the use of brackish water, because it minimizes salt accumulation and ensures maximum leaching by rainfall.(7)

Brackish water has a great potential for use as irrigation water. With the increasing rate of urbanization and industrialization along the eastern seaboard, the shortage of good quality water is becoming more pronounced. For the successful use of a given brackish water for irrigation, the salt tolerance of the crop grown must be considered.

Adverse effects on the quality of water due to irrigation are minimum. Most of the irrigation water is applied using sprinklers. If proper managerial practices are adhered to, there would be very little surface runoff, and the water infiltrating into the soil will be consumed by the plants.

Irrigation with sewage waters was practiced in the United States as early as 1876.(8) The object of these early attempts at sewage irrigation was primarily the disposal of wastes. In recent years, the potential water shortage has directed more attention to the reuse of sewage effluent for irrigation. Health, Education and Welfare(9) and, Federal Water Quality Administration, formerly the Federal Water Pollution Control Administration(10) provide guidelines for the use of sewage effluent for irrigation.

Communities where sewage effluent is used by agriculture can benefit in four major ways.

(1) A safe and satisfactory disposal of water that might otherwise cause stream pollution.

(2) A conservation of other waters for more beneficial or higher value uses.

(3) Agricultural nutrients for the land.

(4) Increased agricultural production.

Agricultural Economic Feasibility. Net returns to irrigation in the NAR are extremely variable. Entirely different conditions exist in the Eastern United States as opposed to the semi-arid areas of the Western United States where irrigation is a necessity for crop production. During most growing seasons in the Northeast, rainfall is adequate and timely for sufficient growth of many crops. In other years crops are damaged by droughts of various lengths. Thus, much of the irrigation is supplemental in the NAR. Payment for the irrigation systems must be covered, for the most part, during these dry years. However, the annual fixed costs continue to plague the farmer during wet seasons as well as dry.

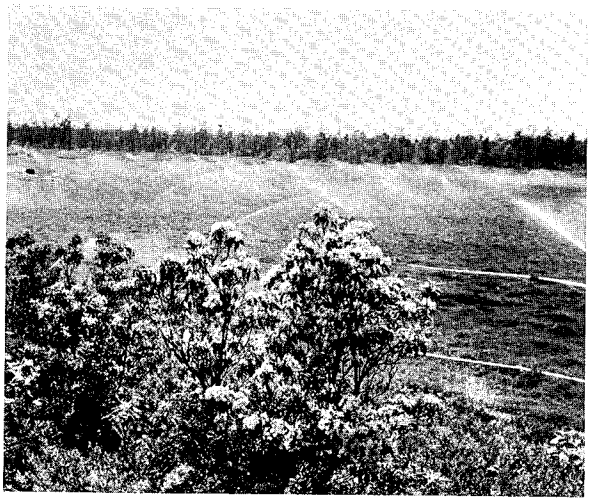
Cost data compiled from the "Agricultural Census" indicate that there is a definite "economy of scale" attached to the number of acres irrigated by a farmer (Figure I-10). The average cost per acre of irrigating one to nine acres is nearly double the cost of irrigating 20 to 29 acres. The cost per acre of irrigating 200 to 499 acres is only slightly more than one-fourth as much as irrigating one to nine acres. It should be remembered that these "economies of scale" are regional averages and would vary in specific situations.

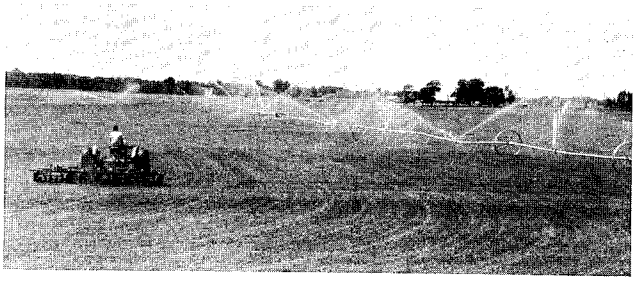
With some geographical exceptions, it is evident that in future years most vegetables, fruits and potatoes will be irrigated in the NAR. Among the factors that will bring about increased irrigation of the above crops are drought periods; timely marketing of these products to take advantage of the highest prices; competition of increased crop quality available from irrigators both here and in other regions; higher yields; more efficient plant use of fertilizer; frost protection for early blooming fruits and berries; and fall frost protection for berries. All of these factors seem to favor investments in irrigation systems, at least for the large grower of fruits, vegetables and potatoes.

It appears that irrigation can be profitable for more farmers than are presently irrigating in the NAR. The returns to irrigation vary greatly by area and type of crop. In general it is likely that irrigation of high value crops will be increasingly necessary as well as profitable. The returns to irrigation of forage crops are marginal and alternative investments might prove more profitable. The cost of developing a reliable water supply may be the limiting factor in some locations.

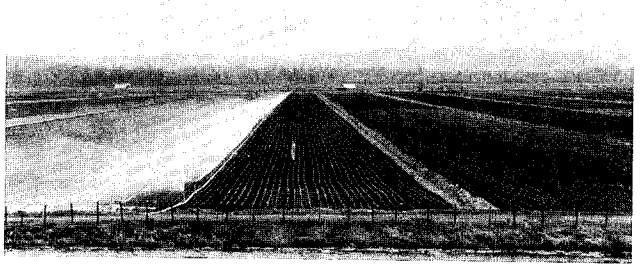
The habit of using irrigation as a standby or insurance against severe crop losses places a limit on the return from irrigation. Benefits can be optimized only when favorable moisture levels are maintained. This requires timely irrigation without waiting for probable rains. It requires that irrigation be based on a sensible means of determining soil moisture deficits. Irrigation requires a high degree of managerial skill that may be better developed when proven technology becomes more universally accepted.

Cranberry crop is protected from frost damage by mist irrigation.





Sod is irrigated and groomed prior to lifting for market.



Vegetables grown on muck soil are being irrigated to improve quality.

Peach orchard is irrigated with sections of perforated pipe

Industrial and Institutional Lawn Irrigation. Counties within the NAR exhibiting at least an annual rural to urban land use shift of 200 acres were selected for further study.[1] This eliminated the more rural counties which are not experiencing population pressures and the more urbanized counties which do not have enough agricultural land remaining in order to maintain that large a shift.

Since differential rates of land use shift are experienced throughout the selected counties in the NAR, a cluster analysis was performed in order to group those counties exhibiting similar growth characteristics into clusters. The cluster model assumes that k different entities can be described by n descriptive variables and further, that the k entities can be broken into a group of subsets or clusters such that the entities within each subset are highly similar and not so similar to any other subset of entities. The measure of similarity between two entities is the common Cartesian distance.(11)

Fifteen variables were used to cluster the 41 selected counties. The resulting eight clusters varied in size from 14 counties in cluster 1 to 1 county in cluster 3. The 15 variables and the eight clusters are shown in Exhibit 1. The most typical county of each cluster was mathematically determined. These counties were then analyzed in great detail utilizing air photos available for two time-periods, approximately 10 years apart (1950-1960). Land use changes were determined from cropland, idle, grassland and forest uses to dense residential, open residential, institutional, commercial, industrial, recreational and airport uses. Contiguous and noncontiguous tracts were studied.

For the irrigation study, the institutional and industrial categories were examined to determine the percentage of the area utilized in lawns. It was determined that on the average 40 percent of the institutional land use and 10 percent of the industrial land use was for lawns.

The earliest air photos available were for the 1950 year. For this study, 1950 was chosen for projection purposes as the base year with zero acres of industrial and institutional lawns. In the case of institutional lawns, it was recognized that there were several acres of lawn prior to 1950. The rate of change between the 1950 and 1960 periods was projected to continue through 2020. No further adjustments were made since rates of industrial growth in the Office of Business Economics economic projections are also relatively constant.

Expansion of the most typical county land use changes to each of the counties within each cluster was accomplished on a percentage basis due to the difference in area of the various counties. Thus, the irrigated lawn acreage was determined for the cluster counties.

1/ Selection was based upon Conservation Needs Inventory sample plots which are a two percent random sample.

For those counties within the NAR not included in the clusters, it was assumed that an average land use shift of 100 acres would be experienced. The average proportion that institutional and industrial land shifts were of the total land use shift in the cluster counties was determined to be six and four percent, respectively. These rates were applied to all noncluster counties to determine lawn irrigation acreage requirements for these areas. Irrigation water requirements are shown in Table I-10.

Golf Course Irrigation. Golf course acreages by counties for 1967 were supplied by the National Golf Foundation. Regression Analysis was used to make projections of golf acreages for the time frame years. Population and income are important in effecting changes in golf acres. Thus, it was necessary to segregate the effect of population from that of income. This was accomplished by regressing golf course acres per thousand population against income. Weekly earnings of workers in manufacturing industries were chosen as the income variable. A weighted average, based on the level of manufacturing employment was formed and deflated to 1958 dollars. In addition, it was assumed that the increases of expenditures on golfing will decrease with each successive increment in income. To allow for this the increases in expenditures with respect to income increments were decreased by .5, .25 and .125 respectively of the average elasticity for the 1955-1965 period.

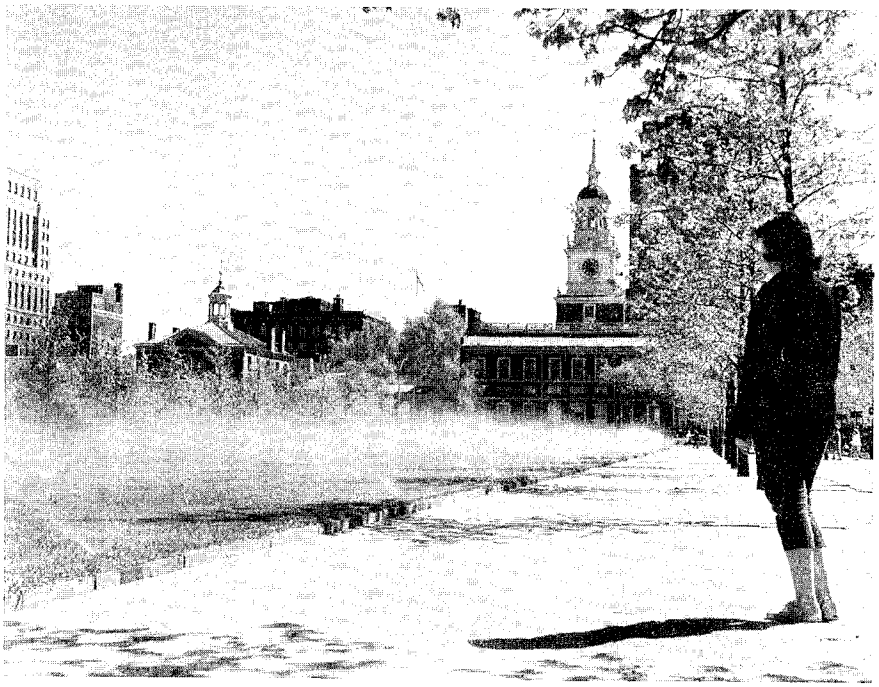
The portion of a golf course which would be irrigated are the tees and greens and fairways. The average percentages of golf courses in tees and greens and fairways are two and 30 respectively. These percentages were applied to the 1967 and projected acreages of golf courses to determine the acreages in tees and greens and fairways (Table I-11).

Table I-11 shows the acreage in tees and greens and fairways which were irrigated in 1967. Almost all the tees and greens and about 49 percent of the fairways were irrigated. In the NAR there was an increase of seven percent in watered fairways from 1966 to 1967.(12) It was assumed that by 1980 all fairways, tees and greens would be irrigated. Tables I-11 and I-10 list the projections of golf course irrigated acreage and water requirements respectively.

Residential Lawn Irrigation. Residential lawn irrigation water requirements are accounted for in Appendix R, Present and Future Water Supply. It is included in the per capita usage of water.

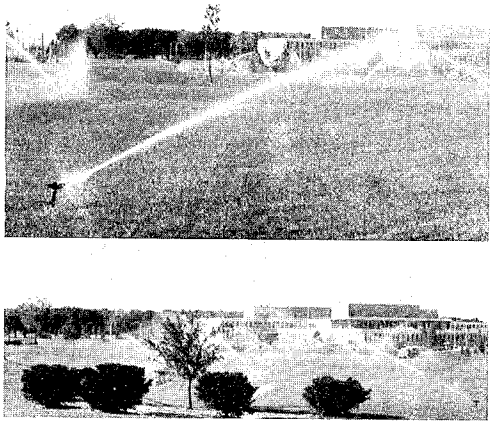
Objectives. Irrigation demands are required for use in plan formulation for three objectives for the time frame years 1980, 2000 and 2020. These demands will be incorporated into Appendix T, General Program and Alternatives, and the Main Report.

The three objectives are National Efficiency, Regional Development and Environmental Quality. The quantities demanded vary with the objectives considered.



Irrigation sprinklers water grass on mall in front of Independence Hall, Philadelphia, Pennsylvania.

Caddie waits for irrigation system to be turned off.



Industrial complex uses water for beautification.

Area summaries were developed and include acreage considered for irrigation, irrigation demands for land and water, costs, and benefits toward each objective. The Area Summaries in tabular form and the methodologies and assumptions are shown in Exhibit 2.

RELATION TO OTHER PARTS OF THE REPORT

The irrigation water requirements compiled in this appendix will be compared to the availability of water in Appendix D - Geology and Ground Water, Appendix E - Flood Control and Water Management on Main Stems and Major Tributaries, and Appendix F - Upstream Flood Prevention and Water Management.

The use of water for irrigation will be based on compatibility and competitiveness with all other uses of water. The uses of water covered in the other appendices include navigation, pollution abatement, recreation, aesthetic and cultural, fish and wildlife, power, municipal and industrial, rural domestic, and livestock. Flood and sediment storage is considered a use in reservoirs.

Any number of uses compatible with the physical limitations of a reservoir site and the available water supply may be combined in a multiple purpose reservoir. The combination of uses may be a number of separate uses added together or there may be joint use of the available water.

If feasible sites are available, but the storage capacity is inadequate to satisfy all needs completely, then an allocation of the storage to the various purposes must be made as equitably as possible, the adopted allocation being a compromise between the various uses. This will be reconciled during plan formulation.

III - REGIONAL SUMMARY

PRESENT STATUS

Trends. Interest in irrigation seems to fluctuate with the weather, especially with variations in rainfall. A recent extended drought in the NAR caused concern about water supplies. The heavy rainfall of 1967 caused many to nearly forget these dry years. A summary of the 1964 Agricultural Census shows that 282,300 acres were irrigated in the Region. The 1959 census indicated that 206,200 acres were irrigated during that year. All indicators point to increasing popularity of irrigation in the Region. More farmers are realizing that irrigation will provide them insurance against crop losses from drought.

Table I-8 presents the estimated irrigated cropland acreages for the Region in 1980, 2000 and 2020. Although the markets for agricultural products will be virtually unlimited in the NAR, expanding population and industrial centers will have an adverse effect on irrigation in some areas. At present much of the irrigated land is located in areas that are rather heavily populated. In future years urban development in these areas is expected to expand causing more favorable market conditions. On the other hand, this development pressure is expected to increase land prices and labor rates to the point where there will be a noticeable decline in agriculture in all the Areas and a decline in irrigation in some Areas.

In 1964 vegetables, potatoes, and fruits made up a very large portion of the total irrigated acreage. It is believed that at some time in the future all of these crops will be irrigated.

Irrigation for nonagricultural purposes such as for golf courses, industrial and institutional lawns, and residential lawns have been increasing and will continue to increase in the future. Table I-10 shows the nonagricultural irrigation water requirements for the time frame years 1980, 2000 and 2020.

Crop Response to Irrigation. In 1955 a technical committee was established in the 12 Northeastern states for the purpose of coordinating and stimulating research in irrigation. This committee, appointed by the Directors of the respective Agricultural Experiment Stations, was composed of one official representative from each Experiment Station and several representatives from the U. S. Departments of Agriculture and Commerce. The report of this committee, "Crop Response to Irrigation in the Northeast" (13), summarizes the findings of the various irrigation experiments. For the purpose of this report the crop responses to irrigation found in the above study are further summarized.

Snap Beans: In Connecticut studies showed average annual yield increases of 2,940 pounds per acre due to light frequent and heavy frequent irrigation. Yield increases for heavy and infrequent irrigations occurred in only two of the five years and averaged 1,590 pounds per acre. Average yields were increased 5,700 pounds per acre in two of five crop years with substantial benefit likely in a third year. Another study showed increases averaging 3,810 pounds per acre in five of the seven crops. Promising results were also found in New Jersey. The increases ranged from 1,350 pounds to 4,470 pounds per acre depending on the moisture levels of the soils. In Geneva, New York, irrigation did not show appreciable results. At Hilton, New York, however, the yield was increased from 2,750 pounds per acre from nonirrigated plots to 3,740 pounds per acre with irrigation. At Ithaca, New York, the yield was increased by 10,050 pounds per acre in 1955 and by 1,980 pounds in 1957.

In the 11 years, 1950 through 1960, yields were increased in 18 of 30 experiments with two other tests suggesting beneficial effects. The maximum increases found were 38 percent in Connecticut, 64 percent in Maryland, 26 percent in New Jersey, and 36 percent in New York.

Generally irrigation improves quality of snap beans. The percentage of crooked and malformed pods was decreased. Larger pods were produced with a larger percentage of seed. About one-fourth of the yield increase was due to a greater average weight per pod. The effect on fiber content varied but generally fibrousness was reduced. The percent moisture content was generally increased.

Cabbage: Cabbage yields in 1950 in Connecticut were increased 76 percent by heavy and frequent irrigation, 42 percent by heavy and infrequent irrigation, and 38 percent by light and frequent irrigation.

In New Jersey a response was obtained in five of six years with an average increase of 7.5 tons per acre. In 1960 no benefit could be attributed to irrigation while in 1957 there was complete crop failure without irrigation.

The New York studies showed an increase of 4.1 tons per acre or a 17 percent gain due to irrigation in a four year study. The increased yields were obtained in two of four years of the study.

Since cabbage requires a high level of soil moisture, increased yields were obtained from irrigation in nine of 13 tests. The best growths were obtained when cabbage was allowed to grow without interruption from planting to maturity.

Potatoes: Potato irrigation was studied much more extensively than other crops due to its greater economic importance in the Region. In 43 separate studies made over approximately a 12 year

period the average increase in yields was 49 hundredweight per acre. To obtain this increase, about three one-inch irrigations were used each crop year. A response was found to irrigation in about three of four years.

Sweet Corn: In 13 different experiments between 1950 and 1960, irrigation significantly increased the yield of corn in only five of them with smaller benefits derived in another three. These studies were conducted in the States of New York, New Jersey, and Connecticut. The proper timing of irrigation is more important to sweet corn than the total amount of water applied. Sweet corn is more sensitive to soil moisture during ear formation than any other time. Therefore, the years when the greatest benefits were derived from irrigation were those when the drought occurred during ear formation.

Significant yield increases were obtained when rainfall was inadequate. In New York during a four year period of study there was an increase of 1.39 tons per acre attributed to irrigation. The increase in yield was the result of more marketable ears per plant, the average weight per ear and the gross yield of unhusked ears. There was also an increase in the percentage of usable corn cut from these ears for canning or freezing.

In New Jersey during the dry season of 1957 the yield was increased 4.43 tons per acre or 129 percent by irrigation. There were significant yield increases in New Jersey in three of six years of the study.

Tomatoes: In 13 of 31 experiments conducted in the States of New York, New Jersey, Maryland, Delaware and Connecticut the yield of tomatoes was increased an average of 7.8 tons per acre or 67 percent. In the other 18 tests the differences due to irrigation were not significant.

Economically, marketable yield is more important than gross yield. Higher yields will be of little benefit to the farmer if the fruit matures so late that they are injured by frost before harvesting. Growth cracks and blossom-end rot are defects which can be partially controlled or minimized by irrigation.

From the above studies it is concluded that irrigation of most high value crops is economically feasible with management being an important qualifying factor.

Forage Crops: The response of forage crops to irrigation was variable. Not even in 1957, an extremely dry season, did all crops respond to irrigation. Between 1953 and 1960 there was a total of 46 irrigation experiments carried out. In only 19 of these were there significant positive responses to irrigation. Nine of these crop year experiments were in 1957. In three observations irrigation actually proved harmful. In the 19 trials in which positive responses were found, the average increase in yield was 0.73 tons per acre of dry forage.

Forage crops appear less sensitive to moisture deficiencies in the soil than most other crops. They seemingly survive short drought periods since they are usually deeper rooted, are grown on heavier soils, and their growth characteristics allow them to experience retarded growth for longer periods until rainfall occurs. Production losses are still sustained but the measurement has been less precise or noticeable. The study concluded that it is doubtful that it would pay most farmers to buy an irrigation system solely for use on forage since an increase of 0.60 to 0.75 tons of dry matter per acre could be obtained only once every two to three years.

Irrigable Land. Table I-3 lists the irrigable soil by land use. There is a large difference between the projected irrigated land in farms (Table I-8) and irrigable soil in crop and pasture. For example, in the year 2020, 480,100 acres of cropland will be irrigated compared to irrigable soil in crop and pasture of 17,225,600 acres in 1958. The difference is so large that it is assumed that out of the 17,225,600 acres of irrigable soil in crop and pasture there will remain at least 480,100 acres to satisfy the projections for irrigated cropland in 2020. It is also assumed that 480,100 acres of irrigable soil will be located sufficiently close to an adequate water source so as to be classified as irrigable land.

Water Sources and Quality. Table I-6 indicates that the source of irrigation water is about evenly divided between ground and surface. Approximately 64.4 percent of the acreage irrigated in 1960 was irrigated through the use of constructed reservoirs (Table I-6). The area encompassed by the 13 states is somewhat larger than the NAR but the totals should approximate NAR values.

The quality of water for irrigation in upstream areas should be adequate for the entire Region. There may be some local situations where the quality will be inadequate but for the most part it will not be a serious problem.

Several studies have proven irrigation with sewage effluent to be technically and economically feasible. Research was conducted concerning the public health aspects of using sewage effluent for irrigation, but there is still a need to establish effluent quality standards for its use.

Types of Systems and Methods of Distribution. The most prevalent method for distributing and applying irrigation water is portable pipe and sprinklers. Table I-6 shows 89.4 percent of the acreage irrigated relied on this system. This percentage is heavily weighted by the Commonwealth of Massachusetts where large acreages are flooded for cranberry irrigation. If Massachusetts is excluded, the percentage of acreage irrigated by portable pipe and sprinklers would increase to 95 percent.

Irrigation Water Requirements. The gross seasonal irrigation water requirement in inches by principal crops is shown in Table I-9. It is based on broad climatic and soil conditions and could

vary in specific locations. These values are translated into regional gross irrigation water requirements (Table I-12) for the years 1980, 2000 and 2020 using the irrigated acreage by crop in Table I-4. Cropland irrigation water requirements will increase to 520,900 acre feet by 2020.

The monthly distribution of gross seasonal irrigation requirements is shown in Table I-13 and Figure I-11. Approximately 90 percent of the irrigation water for cropland in the NAR is required from June through August.

Irrigation water requirements for nonagricultural uses are shown in Table I-10. These nonagricultural uses include industrial and institutional lawns, and golf courses. The irrigation water requirements will increase to 717,400 acre feet by 2020. About 86 percent will be used in golf course irrigation.

FUTURE DEMANDS

Population in the NAR has increased by about 30 percent from 1940 to 1960. Along with this rise in population there has been an increase in the consumption of food and fiber. Not only has the increase been caused by higher population, but also increased personal income has permitted the consumption of costlier foods which normally require larger expenditures of agricultural resources for production.

Accompanying this significant rise in demand has been a general decline in acreage devoted to agricultural production. For instance, land in farms declined by 21 percent from 1954 to 1964. In general, increases in productivity have held production fairly constant over the same period. It is evident that in very few cases, if any, has total production increased as much as demand. At the same time there are few agricultural items which are being produced in sufficient quantity within the Region to meet the requirements. Thus it can be concluded that the Region's agricultural economy in general does not meet the requirements of the Region.

Population is expected to increase by nearly 93 percent by the year 2020 in the NAR. Demand for farm products will also continue to rise. Here are some examples of expected increase in consumption in the Region to the year 2020. Total meat consumption will increase by more than 114 percent; poultry consumption by 145 percent; milk consumption by 68 percent; and egg consumption by 40 percent.

One of the major assumptions made in projecting irrigated acreage was that there will be no attempt by the farmers of the Region to supply the total agricultural product requirements. Thus it is safe to assume that producers in the Region will have little trouble in locating a market for the final consumer product since demand will greatly exceed internal supply. This is true unless producers from outside the Region can supply these markets at a lower cost.

Based on the demand for agricultural products, irrigation could be expanded in areas where it is profitable. There is little evidence that a substantial increase in productivity from within the Region would cause an oversupply of most agricultural products. It is concluded that where irrigation development would be economically feasible and where increased productivity would warrant costs of installation, irrigation could help decrease the Region's production deficit.

MEANS TO SATISFY DEMANDS

Relations with Other Agencies on Other Water Uses and Demands. Hydrologic low flows occur during the June through August season. Stream withdrawals further reduce these low flows often crucial to fish and invertebrate populations, recreational activities, waste transport, and pleasing appearance. The dangers of irrigation withdrawals from near minimum stream flows force consideration of altered demands and non-stream supplies.

The use of water for irrigation will be considered based on its competitiveness with other water uses and demands compiled by other Agencies. These demands can be satisfied by reservoirs, wells and/or directly from streams. If the supply is greater than the demand, there should be no problem as long as the needs can be satisfied economically. If the supply is inadequate to satisfy all needs completely, an allocation will be adopted between the various uses in plan formulation.

General Evaluation of Irrigation Benefits and Costs. Net returns to irrigation are extremely variable from year to year in the NAR because of the quantity and distribution of seasonal rainfall. During most growing seasons in the Northeast, rainfall is sufficient for growth of most feed and forage crops. Many vegetables and fruit crops are presently being grown without irrigation although the proportion of these crops not irrigated is becoming smaller every year.

In future years, irrigation of certain high value crops, such as vegetables, fruits and potatoes, will be necessary from quality as well as a yield standpoint nearly every year. Some vegetable processors who contract certain vegetable crops to farmers already require that irrigation be a condition of the contract.

Results from the study entitled: "Crop Response to Irrigation in the Northeast"(13) found that substantial yield increases or quality increases were received from irrigation on nearly all vegetable crops (see pages I-15, 16 and 17). It is concluded here that it is economical to irrigate high value crops, such as vegetables, potatoes and fruits in the NAR. An evaluation of average responses, in general, indicate that benefits to irrigation from increased yields more than cover the annual cost of irrigation and variable harvesting costs associated with these yields. Increased quality, frost protection, higher plant population, more efficient plant use of fertilizer, assurance of second and third cropping, etc., are other benefits

which make irrigation more attractive to growers of the high value crops. This conclusion is based on the increased popularity in the irrigation of high value crops and the significant increase in yields attributed to irrigation of these crops.

The data to support this conclusion are somewhat limited. It is evident that the return to irrigation is highly dependent upon the amount and distribution of precipitation during the growing season and the managerial ability of the irrigator. Vegetable crops are more sensitive to moisture deficiencies than are forage crops. Vegetables are more sensitive because of shorter growth periods. They are shallower rooted, and they are grown on sandy soils which are more suitable to truck farming. Although total seasonal rainfall is frequently adequate for crop growth in the NAR, there seldom occurs a growing season when drought periods of varying duration do not occur because of untimely distribution of rainfall. Often these droughts are detrimental to both yield and quality of many of the vegetable crops. The timely application of irrigation water is an all important managerial decision affecting irrigation response.

As mentioned above forage crops are less sensitive to moisture deficiencies in the soil than most other crops. The study concluded that it is doubtful that it would pay most farmers to purchase a system for irrigating forage.

Various sources of irrigation cost data are available and most vary considerably. The cost varies because of type of crop, source of water, type of system, and location.

The total cost of irrigation systems for cranberry bogs is now around $500 per acre. There is little "economy of scale" attached to the number of acres irrigated, i.e., costs per acre may not vary significantly with the size of the bog. The trend in the past five years is to install solid-set sprinkler irrigation systems. As the acreage covered increases, so does the investment (larger lines, larger pipe, etc.)

Irrigation budgets prepared by Carncross (14) for 1955 indicate that annual per acre irrigation costs in New Jersey range from $34 on 50 acres of irrigated cropland per farm to $19 on 150 acres and over. The total investment per acre ranged from $195 to $75. Other budgets prepared in Maryland (15) indicate specific annual costs per acre of $40, $43, and $46 for 50 acres; $56 for 53 acres (self-propelled system); and $30.48 for 175 acres (self-propelled system). The total investment per acre ranged from $357 to $186.

A general conclusion can be made that average annual costs for irrigating small acreages in the NAR would range from $30 to $60 per acre and become lower as number of acres increase. The total investment per acre ranged from $350 to $150 per acre. Costs in individual situations could vary from the above range.

NEEDED RESEARCH

Following is a list of some research needs for irrigation development.

Measure consumptive use of major crops under conditions of optimum moisture, fertility, and plant population. Develop improved and additional values of crop coefficients (k values), changes in evapotranspiration as a function of available moisture in various texture classes of irrigated soils, response or yields and quality levels, and moisture extraction patterns in soils of various textural classes.

Further refine the net radiation approach (Jensen and Haise) for determining short period and seasonal consumptive use, and irrigation water requirements.

Study improved economic and practical methods for determining available moisture conditions as a management tool for determining when to irrigate and how much to apply.

Find practical frost protection methods other than use of irrigation systems.

Continue work on evaporation control measures on soil, plant and water surfaces.

Develop design criteria and standards for subsurface application systems.

Develop health standards for the use of sewage effluent as irrigation water for agricultural and nonagricultural uses.

CONCLUSIONS

Irrigated acreages in the Region have increased substantially over the past ten years. This trend is expected to continue, but at a slower rate. By the year 2020 it is expected that there will be about 480,100 acres of agricultural land being irrigated, an increase of 70 percent over present irrigated acreages. Urban and industrial development will eventually cause a decline in agricultural irrigation in some Areas.

The crops most extensively irrigated in the Region have been potatoes, vegetables, fruits, tobacco, cranberries and nursery crops. By 2020 all of these crops in the Region will likely be irrigated. Irrigation of field and forage crops has been and will probably continue to be a marginal operation. It is doubtful that it would pay most farmers to buy an irrigation system solely for use on forage crops.

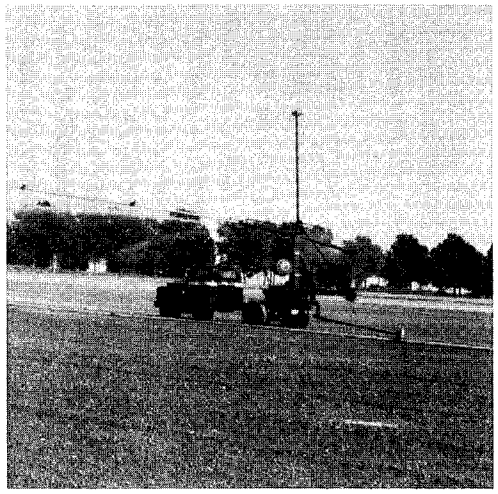
Nonagricultural irrigation will continue to increase at a rapid pace. It is expected to increase by about 270 percent from the present to 2020.

The importance of irrigation water relative to other water needs is highly variable between Areas and between specific locations within Areas. Variation in the importance of irrigation water is caused by water availability and competition between other uses. The priority between these uses will be considered in the plan formulation stage of this Study.

Ninety percent of irrigation withdrawals are required during the months of June through August which correspond with both peak recreational season and hydrologic low flow. It is suggested that withdrawals of water during low-flow periods be made up by upstream storage of high flow to maintain minimum streamflows.

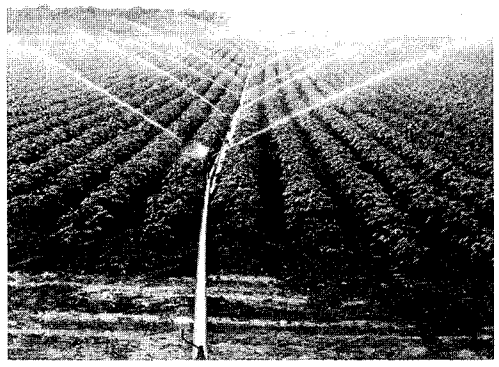
If detailed comprehensive river basin studies are initiated in Areas 1, 9, 13, 15, 16 and 18, it is recommended that detailed irrigation studies be considered. This recommendation is based upon the projected irrigation water requirements (Tables I-10 and I-12), the significance of agricultural irrigation relative to projected cropland (Table I-2), and the water requirement per square mile of drainage area.

Self-powered wheel mounted irrigation system eliminates labor for moving pipe.



Truck mounted boom irrigation system waters new vegetable crop.

Automatic turf system installed underground has pop-up sprinklers.



Portable sprinkler systems are the most common method used to apply irrigation water in the North Atlantic Region.

IV - SUBREGIONAL SUMMARIES

SUBREGION A (Areas 1, 2, 3, 4 and 5)

Trends. The upward trends in irrigation have been much slower in this northernmost subregion. In 1964 less than 1 percent of the Region's irrigated land was located in Subregion A, with an even distribution throughout the Subregion.

Subregion A normally has the heaviest and most frequent precipitation of any of the Subregions. Thus, crop responses to irrigation are less than in the other Subregions. Since Subregion A is the northernmost, the growing season is also the shortest. This short season does not permit the double cropping of vegetables that is prevalent in some of the warmer subregions.

Potatoes have been the most important crop in the Subregion over the years. Recently potato production is becoming rather widely dispersed throughout the country. Prices received by the farmer have fluctuated widely from one year to the next. In some years they have had to absorb substantial losses while in other years profits have been good.

Tremendous water requirement increases are expected as potato acreage irrigation becomes popular.

In recent years sugar beet production has been increasing in the northern portion of the subregion. Because of government controls, prices for beets are much more stable than for potatoes and, in turn, so is the farmer's income.

At present 55 percent of irrigated acreage in the subregion is in potatoes and 19 percent is in vegetables. However, only a very small (less than 1 percent) portion of total acreages of potatoes is irrigated. Underlying reasons for the unpopularity of irrigation could be: (1) relatively high and evenly distributed rainfall, thus low irrigation response; (2) sociological; and (3) highly unstable market prices. The University of Maine, based on recent irrigation studies, is recommending irrigation of potatoes as being a highly profitable practice. This was taken into account in projecting agricultural irrigation water requirements.

Sources and Methods of Distribution. Surface water is the predominant source of water. About 87 percent of the cropland irrigated acres is irrigated through the use of constructed reservoirs. Almost all of the irrigation water is applied with sprinklers.

Irrigation Water Requirements. The gross agricultural irrigation water requirements in the subregion is projected to increase to 83,800 acre feet by 2020. Eighty seven percent of this is projected for Area 1. The availability of water should not be a problem in this subregion. Nearly 88 percent of the irrigation water is required in the months of July and August. Nonagricultural irrigation water requirements will increase to 15,300 acre feet by the year 2020. Eighty-six percent will be used for golf course irrigation.

Irrigable Land. There should be sufficient irrigable land to meet the projections for irrigated land. In 1958 there were 1,130,100 acres of irrigable soil in crop and pasture as compared with the projection of 89,300 acres of irrigated land in 2020.

SUBREGION B (Areas 6, 7, 8, 9 and 10)

Trends. In general, Subregion B has not experienced a high rate of growth in irrigated cropland acres as have the other Subregions since 1949 (Table I-1). With the exception of Area 8, all of the other Areas have been fairly stable in the number of acres irrigated from 1949 to 1964. The Subregion experienced a decline in irrigated acres from 1954 to 1959 but this is believed to have resulted from variations in rainfall.

Areas 8 and 9 have more than 70 percent of the cropland acreage irrigated in Subregion B. Irrigated acreage in the other Areas seems to be fairly evenly distributed among potatoes, sweet corn and other vegetables. Specialty crops are primarily responsible for much of the irrigation in these Areas. Tobacco has been important in Area 8 representing 48 percent of the total acreage irrigated and 72 percent of the Region's tobacco irrigation. Cranberries are by far the most important irrigated crop in Area 9 representing 63 percent of the total acreage irrigated. Cranberries in Area 9 represent more than one-half of berry irrigation in the entire Region. Cranberries are the only crop in the NAR that are presently 100 percent irrigated.

Indications are that agricultural irrigation will increase in Subregion B through 1980 and then decline slowly in the years thereafter. Recent trends in Area 8 indicate that tobacco production is declining and it will continue to decline in future years. Irrigation of vegetables in Area 8 will increase some in the next decade or so but thereafter will probably decline because of urban and industrial encroachment. Cranberry production should be more stable in Area 9 because the land used for cranberry production is not suitable for urban and industrial development. However, pressure from nonagricultural development is likely to cause some irrigation decline of other crops in future years.

Sources and Methods of Distribution. Surface water is the chief source of agricultural irrigation water. More than 68 percent of the irrigated acres is irrigated through the use of constructed reservoirs. Except for Area 9, almost all of the water is applied by using sprinklers. In Area 9 the major method of application is flooding. This is used largely in the production of cranberries. The increased use of sprinklers on cranberries is a recent trend and it can be expected that sprinkler irrigation will continue to increase in the future.

Irrigation Water Requirements. The gross agricultural seasonal irrigation requirements will decrease from 71,600 acre-feet in 1980 to 36,000 acre-feet in 2020 with about 58 percent of the water

requirements being in Area 9. It does not appear that there will be a problem in meeting the agricultural irrigation needs as far as the availability of water for irrigation is concerned. If there is a large demand of water for other needs, the total availability of water will have to be compared with the total needs. If the total needs exceed the total supply the distribution of water will be resolved in plan formulation.

Cropland irrigation water in the Subregion is needed from May through September. The monthly distribution of the irrigation water as a percentage of gross seasonal requirements is 6.0 percent, 24.5 percent, 43,8 percent, 20.9 percent, and 4.8 percent for May, June, July, August and September respectively.

Nonagricultural irrigation water requirements will increase to 200,800 acre feet by 2020. About 89 percent is required for golf course irrigation. Almost 33 percent of the Subregion's water requirement exists in Area 9.

Irrigable Land. In 1958 there were 1,255,100 acres of irrigable soil in crop and pasture as compared with the projection of 31,000 acres of irrigated land in 2020. Thus, there should be sufficient irrigable land to meet the projections of irrigated land.

SUBREGION C (Areas 11, 12 and 13)

Trends. In general, this Subregion has experienced only a modest increase in irrigated acreages over the last 10 to 15 years. Inspection of Table I-1 reveals that irrigation has been reasonably stable with the exception of a substantial acreage increase in Area 12 during the period from 1959 to 1964. Both Areas 11 and 13 have shown very little change in recent years and each had nearly the same number of irrigated acreage in 1964 as in 1954.

The Subregion does not have the internal uniformity that is common to most of the other Subregions. Area 11 is a sparsely populated, rural area where farming is less intensive than in the other two areas. This Area had only 1,000 acres of irrigated land in 1964. On the other hand, Area 13 is a very densely populated area (6,400 per square mile) where a very intensive type of farming is being practiced. This Area had nearly 38,000 irrigated acres in 1964. About 60 percent of the total cropland was irrigated. About 75 percent of the irrigated acreage was in potatoes with nearly all of the remaining acreage in vegetable crops. Area 12 increased from 5,800 irrigated acres in 1954 to 17,300. Since only about 55 percent of these irrigated acres was in vegetables, fruits, and potatoes, it is believed that a relatively large acreage of feed and forage crop was irrigated in Area 12 during the unusually dry summer of 1964.

Total irrigation in Subregion C probably will not change drastically in the near future. However, it is expected that internal changes will be rather pronounced. Irrigated acreage is likely to

increase in Area 12. Area 13, on the other hand, will probably experience substantial decreases in irrigation and farming because of urban and industrial encroachment on agricultural land. It should be noted that no attempt has been made to evaluate future political and institutional restraints in Area 13. Should the preservation of open space become politically desirable, farming (including irrigation) might receive preferential treatment from local legislation.

Sources and Methods of Distribution. Ground water is the major source of agricultural water. This is especially true in Area 13 where almost all the water is obtained from ground water. This is principally due to flat topography and the unavailability of reservoir sites. Only about 33 percent of the irrigated acres is irrigated through the use of constructed reservoirs. Nearly all of the irrigation water is applied using sprinklers.

Irrigation Water Requirements. The gross seasonal agricultural irrigation water requirements will decrease to 36,600 acre-feet by 2020. There will be no agricultural irrigation water required in Area 13 in 2000 and 2020. About 93 percent of the water required in the Subregion will be in Area 12. If there is a conflict between need and supply, it will be resolved in plan formulation.

Agricultural irrigation water in the Subregion is needed from May through September. The monthly distribution of the irrigation water as a percentage of gross seasonal requirement is 1.7 percent, 17.7 percent, 41.3 percent, 32.2 percent, and 7.1 percent for May, June, July, August, and September respectively.

Nonagricultural irrigation water requirements will increase to 132,300 acre feet by 2020. Nearly 90 percent will be used for golf course irrigation. Almost 50 percent of the water needs exists in Area 13.

Irrigable Land. In 1958, there were 2,304,900 acres of irrigable soil in crop and pasture as compared with the projection of 33,100 acres of irrigated land in 2020. There should be sufficient irrigable land to meet the projections of irrigated land.

SUBREGION D (Areas 14, 15 and 16)

Trends. Table I-1 indicates that with the exception of Area 14, this Subregion has experienced a steady growth in irrigated acreage since 1949. A relatively high proportion of cropland in Area 16 is irrigated (11 percent) and more than 85 percent of vegetable, fruit and potato acreages is irrigated. It would seem that Area 16 has reached a relative state of maturity with respect to irrigation of the high value type crops.

Subregion D is the smallest as well as the most densely populated Subregion in the NAR. In spite of this it has nearly 41 percent of the Region's irrigated acreage and more than twice as

much as any other subregion. Area 14 is very small (13 percent of the land area of Subregion D) but has 37 percent of the Subregion's population. A large amount of the irrigated acreage of Subregion D is located in the Delaware-Southern New Jersey portion of the Subregion (Figure I-5). In Area 15, a high percentage of the irrigated acreage is located in the State of Delaware. Area 15 has, by far, the largest acreage of orchards irrigated in the Region (56 percent).

In the future it is expected that irrigation in Area 14 will yield somewhat to the pressures of urban and industrial development. Projections of irrigated acres in Area 15 show increases associated with increases in fruit and vegetable popularity and their comparative advantage in the Subregion. Golf courses will especially increase in the recreational Pocono area. Irrigation in Area 16 is not projected to increase substantially because the high value crops grown are nearly all irrigated at present. Based on past trends, it is doubtful that the total acreage of vegetables (irrigated and nonirrigated) will increase substantially in the near future.

Sources and Methods of Distribution. The source of agricultural irrigation water is about evenly divided between ground and surface sources. More than 64 percent of the irrigated acres is irrigated through the use of constructed reservoirs. Almost all the water is applied using sprinklers with the exception of Area 16 where cranberries are irrigated by flooding.

Irrigation Water Requirements. The gross agricultural seasonal irrigation water requirements in 1980, 2000 and 2020 are 175,100 acre-feet, 192,900 acre-feet, and 155,700 acre-feet respectively. These are relatively large quantities and will be compared with the other water needs. If there is a conflict between need and supply it will be resolved in plan formulation.

Irrigation water in the Subregion is needed from May through September. The monthly distribution of the irrigation water as a percentage of gross seasonal requirement is 7.5 percent, 27.0 percent, 40.7 percent, 21.2 percent, and 3.6 percent for May, June, July, August, and September respectively.

Nonagricultural irrigation water requirements will increase to 179,700 acre feet by 2020. About 83 percent is required for golf course irrigation. Nearly 67 percent of the water needs exists in Area 15.

Irrigable Land. In 1958, there were 2,752,800 acres of irrigable soil in crop and pasture as compared with the projection of 142,600 irrigated acres in 2020. There should be sufficient irrigable land to meet the projections for irrigated land. There may be a problem in Area 16 where the irrigated land in 2020 will be a relatively large portion (22 percent) of the 1958 irrigable soil in crop and pasture. Thus, we can conclude with less certainty that there will be sufficient irrigable land to meet the

projections for irrigated land in 2020 in Area 16. There are 454,800 acres of irrigable soil in Area 16 in "Other" uses which may be available as irrigable land, but it is beyond the scope of this study to determine this.

SUBREGION E (Areas 17 and 18)

Trends. Irrigation in this Subregion has experienced a relatively large increase during the period from 1954 to 1964 (Table I-1). Much of the growth of irrigation has been in Area 18 which has increased by 162 percent from 1954 to 1964. Area 18 also contains about 69 percent of the Subregion's irrigated land although Area 17 has nearly 79 percent of the total land area in the Subregion. Thus, it can be readily seen that Area 18 is irrigated much more intensively than Area 17.

Area 18 has the largest total acreage of vegetables, fruits and potatoes in the Region. Nearly 70 percent of the acres irrigated in Area 18 is in vegetable crops; 18 percent is in potatoes. Of the vegetables, snap beans are the most important. In Area 17, 35 percent of the irrigated acreage is in the "all other crop" category. This indicates that relatively more feed and forage crops are irrigated in Area 17.

Area 18 presents one of the largest potential areas for increases in irrigation in the NAR. Vegetable crops are expected to continue to be a very important part of the agricultural economy in Area 18. Irrigation of specialty crops is about to increase in Area 17 due to a nearby increasing urban market and improved interstate highway systems. Area 17 will also experience an increase in irrigation of fruits, vegetables and, where economically feasible, feed crops.1/

Sources and Methods of Distribution. The major source of agricultural irrigation water is from surface water sources. More than 64 percent of the irrigated acreage is irrigated through the use of constructed reservoirs. Almost all the water is applied through the use of sprinklers.

Irrigation Water Requirements. The gross agricultural seasonal irrigation requirements will increase to 150,800 acre-feet in 2020. This is a relatively large quantity of water and it may be in competition with other water needs. If the needs exceed the supply, the allocation of the water will be resolved in plan formulation.

Irrigation water in the Subregion is needed from May through September. The monthly distribution of the irrigation water as a percentage of gross seasonal requirement is 6.5 percent, 30.3 percent, 35.8 percent, 25.6 percent, and 1.8 percent for May, June, July, August, and September respectively.

1/ The projected irrigated acreages for this appendix are lower than the projected irrigated acreages in the Susquehanna River Basin Type 2 Study(16). These differences are due to a variation in methodology and assumptions used in each study.

Nonagricultural irrigation water requirements will increase to 96,500 acre feet by 2020. Approximately 82 percent will be used for golf course irrigation. About 65 percent of the water needs exists in Area 17.

Irrigable Land. In 1958 there were 5,637,800 acres of irrigable soil in crop and pasture as compared with the projection of 134,800 acres of irrigated land in 2020. There should be sufficient irrigable land to meet the projections for irrigated land.

SUBREGION F (Areas 19, 20 and 21)

Trends. Subregion F is the southernmost Subregion of the NAR. In general, irrigation has not increased as rapidly here as in neighboring Subregions D and E. Area 19 has experienced an irrigated acreage increase from 1954 to 1964, but Areas 20 and 21 have both had slight decreases during the same period (Table I-1).

In 1964 the Subregion had only seven percent of the Region's irrigated land but nearly 19 percent of the cropland. At the same time Table I-5 shows that 48 percent of the irrigated land in the Subregion is in the "all other crop" category. This indicates that the irrigation of feed crops and possibly forage is relatively more important here than in any other Subregion. The most important of the high value crops irrigated in the Subregion are fruits, tobacco, and nursery crops. Area 19 has 3,420 acres of fruits irrigated, second only to Area 15 in the Region. The irrigation of vegetable crops is not popular in the Subregion, representing only 10 percent of the irrigated acreage.

Irrigation is expected to experience growth in the Subregion in future years, especially in Area 19, where the irrigation of fruits will increase substantially. The irrigation of tobacco should increase in Areas 19 and 21. Since the production of vegetables and potatoes is only of minor importance in Subregion F, it is doubtful that irrigation will experience substantial increases in future years.

Sources and Methods of Distribution. Surface water is the major source of agricultural irrigation water. More than 85 percent of the irrigated acreage is irrigated through the use of constructed reservoirs. Almost all of the irrigation water is applied using sprinklers.

Irrigation Water Requirements. The gross agricultural seasonal irrigation requirements for 1980, 2000 and 2020 are 47,500 acre-feet, 64,300 acre-feet, and 57,400 acre-feet respectively. There should be no problem with meeting the irrigation needs in Areas 20 and 21. Eighty-five percent of the total Subregion irrigation requirements is in Area 19. Competition between water needs and available supply will determine whether the irrigation needs for Area 19 will be met.

Irrigation water in the Subregion is needed from May through September. The monthly distribution of the irrigation water as a percentage of gross seasonal requirement is 3.8 percent, 25.6 percent, 39.8 percent, 27.2 percent, and 3.7 percent for May, June, July, August, and September respectively.

Nonagricultural irrigation water requirements will increase to 92,800 acre feet by 2020. Nearly 80 percent is required for use in irrigating golf courses. Approximately 61 percent of the water need exists in Area 19.

Irrigable Land. In 1958, there were 4,144,900 acres of irrigable soil in crop and pasture compared with a projected 49,300 acres of irrigated land in 2020. There should be sufficient irrigable land to meet the projections for irrigated land.

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TABLE I - 1

IRRIGATED LAND IN FARMS, PAST AND PRESENT

Subregion and Area	1949	1954	1959	1964
	Acres			
Subregion A				
1	500	100	400	300
2	200	1/	100	700
3	100	200	100	100
4	300	100	100	700
5	300	200	100	600
Subtotal A	1,400	600	800	2,400
Subregion B				
6	2,100	800	1,800	2,400
7	2,900	4,300	2,600	5,700
8	8,200	10,200	7,700	14,200
9	15,000	17,600	15,400	17,600
10	2,600	4,300	1,200	5,100
Subtotal B	30,800	37,200	28,700	45,000
Subregion C				
11	200	900	1,500	1,000
12	2,700	6,500	5,800	17,300
13	12,200	37,700	32,900	37,900
Subtotal C	15,100	45,100	40,200	56,200
Subregion D				
14	4,300	9,300	8,700	8,800
15	23,400	48,600	66,400	83,800
16	6,100	12,400	18,700	22,800
Subtotal D	33,800	70,300	93,800	115,400
Subregion E				
17	1,700	9,300	7,600	13,700
18	2,600	11,400	23,600	29,900
Subtotal E	4,300	20,700	31,200	43,600
Subregion F				
19	400	8,200	6,300	13,500
20	1/	2,600	1,200	1,900
21	1/	4,400	4,000	4,300
Subtotal F	400	15,200	11,500	19,700
REGION TOTAL	85,800	189,100	206,200	282,300

Source: U.S. Census of Agriculture. Data rounded to nearest 100 acres.
1/ Less than 50 acres.

TABLE I - 2

IRRIGATED LAND IN FARMS, PRESENT AND PROJECTED
AS A PERCENT OF TOTAL CROPLAND

Subregion and Area	1964	1980	2000	2020
Subregion A				
1	.1	10.4	32.5	94.0
2	.3	1.1	4.7	26.0
3	.1	.3	1.8	9.3
4	.5	2.5	7.0	15.2
5	.3	1.0	3.4	8.1
Subtotal A	.2	4.8	16.2	50.2
Subregion B				
6	1.4	3.5	7.6	17.3
7	3.4	6.2	11.1	11.7
8	2.4	8.3	9.0	10.0
9	12.2	25.0	31.8	60.4
10	2.2	5.7	6.0	6.5
Subtotal B	3.4	9.1	11.5	17.3
Subregion C				
11	.1	.2	.3	.5
12	1.3	2.6	4.0	6.7
13	60.0	95.0	-	-
Subtotal C	2.2	2.3	2.6	3.7
Subregion D				
14	3.8	9.1	11.5	11.2
15	4.6	8.6	14.9	16.5
16	10.7	36.2	42.2	51.3
Subtotal D	5.1	10.4	16.9	19.7
Subregion E				
17	.3	.9	1.4	2.2
18	1.7	4.5	9.0	11.5
Subtotal E	.8	1.9	3.5	4.8
Subregion F				
19	.7	1.9	3.6	4.0
20	.3	.5	.6	.9
21	.7	1.0	1.5	2.0
Subtotal F	.7	1.5	2.7	3.1
REGION TOTAL	1.8	3.5	5.6	7.6

TABLE I - 3

IRRIGABLE SOIL BY LAND USE, 1958

Subregion and Area	Crop & Pasture	Other	Total 1/
	1000 Acres		
Subregion A			
1	394.1	665.5	1,059.6
2	165.0	241.3	406.3
3	248.3	321.7	570.0
4	106.6	266.2	372.8
5	216.1	578.7	794.8
Subtotal A	1,130.1	2,073.4	3,203.5
Subregion B			
6	209.0	578.8	787.8
7	216.9	276.8	493.7
8	358.2	310.2	668.4
9	150.3	475.1	625.4
10	320.7	307.3	628.0
Subtotal B	1,255.1	1,948.2	3,203.3
Subregion C			
11	616.1	503.5	1,119.6
12	1,595.0	1,502.4	3,097.4
13	93.8	217.1	310.9
Subtotal C	2,304.9	2,223.0	4,527.9
Subregion D			
14	253.4	224.2	477.6
15	2,334.5	1,442.1	3,776.6
16	164.9	454.8	619.7
Subtotal D	2,752.8	2,121.1	4,873.9
Subregion E			
17	3,750.2	2,445.9	6,196.1
18	1,887.6	1,397.7	3,285.3
Subtotal E	5,637.8	3,843.6	9,481.4
Subregion F			
19	2,547.8	1,390.4	3,938.2
20	677.9	1,275.6	1,953.5
21	919.2	1,878.4	2,797.6
Subtotal F	4,144.9	4,544.4	8,689.3
REGION TOTAL	17,225.6	16,753.7	33,979.3

Source: 1958 Conservation Needs Inventory
1/ Total of SCS Land Capability Classes I, II, and III

TABLE I - 4

IRRIGATED LAND IN FARMS, AND ACREAGES OF SPECIFIED CROPS, 1964

Subregion and Area	Irrigated Land in Farms	Corn For Grain	Potatoes	Tomatoes	Sweet Corn	Snap Beans	Cucumbers	Cabbage	Lettuce and Romaine	Other Vegetables	Tobacco	Berries	Land in Orchard	Total Nursery	All Other Crops
Subregion A															
1	300	-	270	-	-	-	-	-	-	-	-	-	-	-	30
2	700	-	620	-	20	-	-	-	-	-	-	-	-	-	60
3	100	-	10	-	20	-	-	-	-	50	-	-	-	-	20
4	700	-	300	-	40	-	-	10	-	170	-	-	-	90	90
5	600	-	120	-	50	-	-	20	20	60	-	310	-	-	20
Subtotal A	2,400	-	1,320	-	130	-	-	30	20	280	-	310	-	90	220
Subregion B															
6	2,400	-	600	-	310	-	-	150	260	430	-	-	-	40	610
7	5,700	-	180	70	1,340	190	-	360	110	1,420	-	50	-	280	1,700
8	14,200	-	1,890	150	1,000	40	-	230	40	1,460	6,810	40	-	1,070	1,470
9	17,600	-	580	260	1,060	140	-	320	180	1,810	-	11,130	-	650	1,470
10	5,100	-	2,030	170	330	90	-	200	-	570	170	-	-	290	1,250
Subtotal B	45,000	-	5,280	650	4,040	460	-	1,260	590	5,690	6,980	11,220	-	2,330	6,500
Subregion C															
11	1,000	-	100	20	20	-	-	-	-	40	-	-	-	60	760
12	17,300	200	1,040	200	2,720	860	30	240	1,170	2,840	-	60	-	320	7,620
13	37,900	20	28,670	210	850	240	320	1,150	410	3,560	-	380	-	2,090	-
Subtotal C	56,200	220	29,810	430	3,590	1,100	350	1,390	1,580	6,440	-	440	-	2,470	8,380
Subregion D															
14	8,800	50	3,540	240	1,110	50	40	880	340	2,110	-	60	100	280	-
15	83,800	1,200	14,180	10,310	6,060	10,020	1,770	1,910	2,280	18,610	-	4,680	9,040	3,270	470
16	22,800	100	3,880	1,930	1,300	360	520	980	790	3,410	-	4,440	2,050	1,500	1,540
Subtotal D	115,400	1,350	21,600	12,480	8,470	10,430	2,330	3,770	3,410	24,130	-	9,180	11,190	5,050	2,010
Subregion E															
17	13,700	1,040	2,400	780	900	530	40	440	10	970	-	190	1,060	480	4,860
18	29,900	1,140	5,450	2,500	2,130	5,300	2,200	1,370	-	7,210	260	420	90	1,040	790
Subtotal E	43,600	2,180	7,850	3,280	3,030	5,830	2,240	1,810	10	8,180	260	610	1,150	1,520	5,650
Subregion F															
19	13,500	200	100	110	160	100	-	-	-	340	1,190	40	3,420	1,580	6,260
20	1,900	-	-	30	30	-	-	10	-	170	-	-	140	50	1,470
21	4,300	-	40	30	160	120	60	20	-	740	1,000	60	280	90	1,700
Subtotal F	19,700	200	140	170	350	220	60	30	-	1,250	2,190	100	3,840	1,720	9,430
REGION TOTAL	282,300	3,950	66,000	17,010	19,610	18,040	4,980	8,290	8,610	45,970	9,430	21,860	16,180	13,180	32,190

Source: U.S. Census of Agriculture

TABLE I - 5

PERCENTAGE OF IRRIGATED LAND IN FARMS DISTRIBUTED BY CROP, 1964

Subregion and Area	Irrigated Land in Farms	Corn For Grain	Potatoes	Tomatoes	Sweet Corn	Snap Beans	Cucumbers	Cabbage	Lettuce: Romaine	Other Vegetables	Tobacco	Berries	Land in Orchard	Total Nursery	All Other Crops
Subregion A															
1	100	-	90.0	-	-	-	-	-	-	-	-	-	-	-	10.0
2	100	-	88.6	-	2.8	-	-	-	-	-	-	-	-	-	8.6
3	100	-	10.0	-	20.0	-	-	-	-	50.0	-	-	-	-	20.0
4	100	-	42.9	-	5.7	-	-	1.4	-	24.3	-	-	-	12.9	12.8
5	100	-	20.0	-	8.3	-	-	3.3	3.3	10.0	-	51.8	-	-	3.3
Subtotal A	100	-	55.0	-	5.4	-	-	1.3	.8	11.7	-	12.9	-	3.8	9.1
Subregion B															
6	100	-	25.0	-	12.9	-	-	6.3	10.8	17.9	-	-	-	1.7	25.4
7	100	-	3.2	1.2	23.5	3.4	-	6.3	1.9	24.9	-	.9	-	4.9	29.8
8	100	-	13.3	1.1	7.0	.3	-	1.6	.3	10.3	48.0	.3	-	7.5	10.3
9	100	-	3.3	1.5	6.0	.8	-	1.8	1.0	10.3	-	63.3	-	3.7	8.3
10	100	-	39.8	3.3	6.5	1.8	-	3.9	-	11.2	3.3	-	-	3.9	24.5
Subtotal B	100	-	11.7	1.4	9.0	1.0	-	2.8	1.3	12.6	15.5	24.9	-	5.2	14.5
Subregion C															
11	100	-	10.0	2.0	2.0	-	-	-	-	4.0	-	-	-	6.0	76.0
12	100	1.2	6.0	1.2	15.7	5.0	.2	1.4	6.8	16.4	-	.3	-	1.8	44.0
13	100	.1	75.6	.6	2.2	.6	.8	3.0	1.1	9.4	-	1.0	-	5.6	-
Subtotal C	100	.4	53.0	.8	6.4	2.0	.6	2.5	2.8	11.4	-	.8	-	4.4	14.9
Subregion D															
14	100	.6	40.2	2.7	12.6	.6	0.4	10.0	3.9	24.0	-	.7	1.1	3.2	-
15	100	1.4	16.9	12.3	7.2	12.0	2.1	2.3	2.7	22.2	-	5.6	10.8	3.9	.6
16	100	.4	17.0	8.5	5.7	1.6	2.3	4.3	3.5	14.9	-	19.5	9.0	6.6	6.7
Subtotal D	100	1.2	18.7	10.8	7.3	9.0	2.0	3.3	3.0	20.9	-	8.0	9.7	4.4	1.7
Subregion E															
17	100	7.6	17.5	5.7	6.6	3.9	.3	3.2	.1	7.1	-	1.4	7.7	3.5	35.4
18	100	3.8	18.2	8.4	7.1	17.7	7.4	4.6	-	24.1	.9	1.4	.3	3.5	2.6
Subtotal E	100	5.0	18.0	7.5	6.9	13.4	5.1	4.2	1/	18.8	.6	1.4	2.6	3.5	13.0
Subregion F															
19	100	1.5	.7	.8	1.2	.7	-	-	-	2.5	8.8	.3	25.4	11.7	46.4
20	100	-	-	1.6	1.6	-	-	.5	-	8.9	-	-	7.4	2.6	77.4
21	100	-	.9	.7	3.7	2.8	1.4	.5	-	17.2	23.3	1.4	6.5	2.1	39.5
Subtotal F	100	1.0	.7	.9	1.8	1.1	.3	.2	-	6.3	11.1	.5	19.5	8.7	47.9
REGION TOTAL	100	1.4	23.4	6.0	6.9	6.4	1.8	2.9	2.0	16.3	3.3	7.8	5.7	4.7	11.4

Source: U.S. Census of Agriculture

1/ Less than 0.05

TABLE I - 6

PER CENT OF AGRICULTURAL ACRES IRRIGATED BY STATE.1960:
BY SOURCE OF WATER, METHOD OF APPLICATION, AND USE OF CONSTRUCTED RESERVOIRS.

STATE	Source of Water				Methods of Application of Water				Use of
	Ground-water[1]	Surface Water[2]	Municipal Water Supply Systems[3]	Other[4]	Portable Pipe & Sprinklers	Fixed Overhead Pipes	Flood-ing	Sub-irri-gation	Con-structed Reservoirs
Maine	26.0	69.7	4.3	-	98.2	0.7	1.1	-	86.5
New Hampshire	18.7	75.8	5.5	-	98.3	1.7	-	-	75.3
Vermont	16.7	78.2	5.1	-	76.3	5.0	10.4	8.3	78.1
Massachusetts	28.5	65.3	6.2	-	37.0	2.0	61.0	-	62.0
Rhode Island	37.0	34.8	21.6	6.6	95.7	1.0	3.3	-	68.5
Connecticut	27.3	67.6	5.1	-	91.5	8.5	-	5/	84.3
New York	70.8	23.7	2.7	2.8	97.7	1.9	0.1	0.3	32.8
New Jersey	55.7	43.4	0.7	0.2	89.7	3.7	6.2	0.4	73.0
Pennsylvania	30.3	65.2	3.8	0.7	93.4	4.8	1.8	5/	64.2
Delaware	48.6	51.3	0.1	-	99.3	0.2	-	0.5	81.5
Maryland	31.3	66.6	1.3	0.8	98.7	1.2	0.1	5/	85.7
Virginia	20.7	79.1	0.2	-	98.8	0.9	0.2	0.1	85.4
West Virginia	0.6	99.1	0.3	-	99.2	0.8	-	-	27.1
TOTAL	48.7	48.5	2.0	0.8	89.4	2.6	7.8	0.2	64.4

Source: U.S. Census of Agriculture

1/ Wells and springs and seepage are considered to be ground sources of water.

2/ Natural streams and rivers, farm runoff, natural lakes and natural ponds, and drainage ditches are considered to be surface sources of water.

3/ Natural source of water can be either surface or ground.

4/ May include such sources as canals (for example, the Erie Barge Canal of New York).

5/ Less than 0.05.

TABLE I - 7

TOTAL SPECIALIZED CROPS, PRESENT AND PROJECTED

Subregion and Area	1964	1980	2000	2020
	1000 Acres			
Subregion A				
1	.3	70.7	70.7	70.7
2	.6	4.6	4.1	3.5
3	.1	3.4	2.9	2.9
4	.5	3.9	3.4	2.9
5	.6	3.1	2.6	2.3
Subtotal A	2.1	85.7	83.7	82.3
Subregion B				
6	1.8	4.3	2.7	2.7
7	3.7	9.4	3.7	1.6
8	4.8	22.5	13.1	7.6
9	15.5	20.8	14.4	14.4
10	3.4	7.0	3.5	1.8
Subtotal B	29.2	64.0	37.4	28.1
Subregion C				
11	.2	5.4	1.8	1.8
12	9.2	43.3	28.3	28.3
13	35.8	13.6	-	-
Subtotal C	45.2	62.3	30.1	30.1
Subregion D				
14	8.4	9.1	5.4	2.4
15	78.9	110.4	125.8	94.5
16	19.7	32.6	32.6	32.6
Subtotal D	107.0	152.1	163.8	129.5
Subregion E				
17	7.3	54.3	33.5	40.9
18	26.7	90.4	81.6	77.1
Subtotal E	34.0	144.7	115.1	118.0
Subregion F				
19	4.3	54.7	42.5	37.4
20	.4	5.9	3.0	2.0
21	1.5	6.7	5.7	5.4
Subtotal F	6.2	67.3	51.2	44.8
REGION TOTAL	223.7	576.1	481.3	432.8

TABLE I - 8

IRRIGATED LAND IN FARMS, PRESENT AND PROJECTED 1/

Subregion and Area	1964	1980	2000	2020
	Acres			
Subregion A				
1	300	20,500	43,200	77,000
2	700	700	1,400	3,900
3	100	300	1,000	2,700
4	700	1,600	2,500	3,200
5	600	800	1,900	2,500
Subtotal A	2,400	23,900	50,000	89,300
Subregion B				
6	2,400	2,900	3,000	3,000
7	5,700	5,300	4,100	1,800
8	14,200	24,800	14,400	8,400
9	17,600	22,900	15,800	15,800
10	5,100	7,700	3,900	2,000
Subtotal B	45,000	63,600	41,200	31,000
Subregion C				
11	1,000	1,500	2,000	2,000
12	17,300	25,300	31,100	31,100
13	37,900	15,000	-	-
Subtotal C	56,200	41,800	33,100	33,100
Subregion D				
14	8,800	10,000	6,000	2,700
15	83,800	117,000	137,800	104,000
16	22,800	35,900	35,900	35,900
Subtotal D	115,400	162,900	179,700	142,600
Subregion E				
17	13,700	29,300	36,900	45,000
18	29,900	58,700	89,800	89,800
Subtotal E	43,600	88,000	126,700	134,800
Subregion F				
19	13,500	32,800	46,700	41,100
20	1,900	2,200	2,200	2,200
21	4,300	5,900	6,300	6,000
Subtotal F	19,700	40,900	55,200	49,300
REGION TOTAL	282,300	421,100	485,900	480,100

1/ Projected acreages are for high value crops. These acreages are used in plan formulation for the National Efficiency Objective.

TABLE I - 9

CROP GROSS SEASONAL IRRIGATION REQUIREMENTS[1], INCHES

Area	Corn for Grain[2]	Potatoes	Tomatoes	Sweet Corn	Snap Beans		Cucumbers	Cabbage		Lettuce and Romaine		Small Vegetables	Land in Orchard	Tobacco	Cran-berries	Nursery	Alfalfa	Corn Sillage
					1st Crop	2nd Crop		1st Crop	2nd Crop	1st Crop	2nd Crop							
1	-	9.2	-	13.7	-	-	-	-	-	-	-	5.2	-	-	-	-	-	-
2	-	10.4	-	15.1	-	-	-	-	-	-	-	6.2	-	-	-	-	-	-
3	-	10.4	-	15.1	-	-	-	-	-	-	-	6.2	-	-	-	-	-	-
4	-	11.3	-	16.1	-	-	-	-	-	-	-	7.1	-	-	-	10.5	21.7	15.5
5	-	11.6	-	16.3	-	-	-	-	-	-	-	7.1	-	-	-	-	-	-
6	-	11.5	-	16.2	-	-	-	-	-	-	-	7.1	-	-	-	-	21.5	15.6
7	-	12.8	11.1	13.7	5.5	-	-	6.2	-	7.1	-	7.3	-	-	-	10.5	18.3	12.7
8	-	13.7	10.7	14.1	5.3	-	-	5.8	-	6.9	-	-	-	10.2	-	11.9	19.8	12.7
9	-	14.6	12.0	15.0	6.0	-	-	6.4	-	7.4	-	-	-	-	17.8	10.8	22.4	14.3
10	-	13.3	10.3	13.5	5.2	-	-	5.5	-	6.7	-	-	-	10.2	-	11.9	19.5	12.7
11	-	13.8	-	-	-	-	-	-	-	-	-	7.3	-	-	-	9.9	16.6	15.5
12	13.9	11.4	9.9	12.8	4.3	-	-	7.2	-	6.9	-	8.4	-	-	-	10.6	19.2	12.1
13	-	12.9	9.5	12.6	3.7	-	5.5	4.6	-	7.3	-	-	-	-	-	11.2	-	-
14	-	11.7	10.2	13.5	-	-	-	3.3	6.0	6.3	7.4	-	16.0	-	-	8.8	-	-
15	14.7	13.5	12.2	15.5	4.6	6.0	8.4	4.5	6.3	6.9	7.6	-	17.0	-	16.0	10.8	-	-
16	-	16.2	14.8	18.4	6.3	6.9	10.7	6.4	7.2	7.1	7.7	-	22.2	-	16.2	13.2	26.7	17.5
17	17.7	17.4	14.5	12.5	4.9	7.7	-	-	-	-	-	-	21.7	-	-	-	-	-
18	14.3	13.8	11.8	15.2	4.6	6.2	4.8	4.8	9.0	-	-	6.7	-	-	-	9.7	-	-
19	13.3	12.8	-	-	3.0	-	-	-	-	-	-	5.2	17.8	11.0	-	8.2	19.9	-
20	14.0	-	-	-	-	-	-	-	-	-	-	7.6	21.1	-	-	-	9.7	-
21	13.9	-	-	16.5	7.5	-	-	-	-	-	-	7.5	21.2	12.9	-	-	10.4	-

1/ These are "dry season" irrigation requirements. The effective rainfall is determined from the 90% chance occurrence. In 9 out of 10 years, the actual irrigation water needed for optimum growth would be equal to or less than the values shown in this table.

2/ The effective rainfall is determined from the 80% chance occurrence.

3/ These are weighted averages of the eight sub-basins in the August 1967 Draft of Susquehanna River Basin Study, Agricultural Water Requirements-Irrigation.

TABLE I-10

NONAGRICULTURAL IRRIGATION WATER REQUIREMENTS

Subregion and Area	GOLF				INDUSTRIAL				INSTITUTIONAL				TOTAL			
	1967	1980	2000	2020	1967	1980	2000	2020	1967	1980	2000	2020	1967	1980	2000	2020
	1000 acre-feet															
Subregion A																
1	.4	.5	.9	1.3	1/	1/	1/	1/	1/	1/	.1	.1	.4	.5	1.0	1.4
2	.5	.7	1.2	1.7	1/	1/	.1	.1	.1	.1	.2	.2	.6	.8	1.5	2.0
3	.7	1.1	1.8	2.6	1/	.1	.1	.1	.1	.1	.2	.3	.8	1.3	2.1	3.0
4	1.0	1.5	2.5	3.7	1/	1/	.1	.1	.1	.1	.2	.2	1.1	1.6	2.8	4.0
5	1.1	1.6	2.6	3.9	.1	.1	.2	.3	.2	.3	.5	.7	1.4	2.0	3.3	4.9
Subtotal A	3.7	5.4	9.0	13.2	.1	.2	.5	.6	.5	.6	1.2	1.5	4.3	6.2	10.7	15.3
Subregion B																
6	3.1	4.6	7.4	11.0	.2	.4	.7	.9	.3	.5	.8	1.2	3.6	5.5	8.9	13.1
7	8.4	12.7	20.4	30.3	.5	.8	1.4	1.9	.6	1.0	1.7	2.3	9.5	14.5	23.5	34.5
8	10.4	15.6	25.2	37.3	.3	.6	1.0	1.4	.9	1.6	2.7	3.8	11.6	17.8	28.9	42.5
9	16.6	25.0	40.3	60.0	.4	.8	1.3	1.8	.9	1.5	2.5	3.5	17.9	27.3	44.1	65.3
10	10.9	16.5	26.5	39.4	.5	.8	1.3	1.9	1.0	1.8	2.9	4.1	12.4	19.1	30.7	45.4
Subtotal B	49.4	74.4	119.8	178.0	1.9	3.4	5.7	7.9	3.7	6.4	10.6	14.9	55.0	84.2	136.1	200.8
Subregion C																
11	4.4	6.6	10.6	15.7	.1	.2	.4	.5	.3	.6	1.0	1.3	4.8	7.4	12.0	17.5
12	12.5	18.9	30.4	45.1	.3	.5	.8	1.1	.6	1.1	1.9	2.7	13.4	20.5	33.1	48.9
13	17.9	27.0	43.5	64.7	.1	.1	.2	.3	.2	.4	.6	.9	18.2	27.5	44.3	65.9
Subtotal C	34.8	52.5	84.5	125.5	.5	.8	1.4	1.9	1.1	2.1	3.5	4.9	36.4	55.4	89.4	132.3
Subregion D																
14	11.2	16.9	27.2	40.4	.2	.4	.6	.8	.4	.8	1.3	1.8	11.8	18.1	29.1	43.0
15	26.5	40.0	64.3	95.6	1.1	1.9	3.2	4.5	4.6	8.1	13.5	18.9	32.2	50.0	81.0	119.0
16	3.8	5.7	9.2	13.6	.2	.3	.5	.6	.9	1.5	2.5	3.5	4.9	7.5	12.2	17.7
Subtotal D	41.5	62.6	100.7	149.6	1.5	2.6	4.3	5.9	5.9	10.4	17.3	24.2	48.9	75.6	122.3	179.7
Subregion E																
17	14.9	22.5	36.2	53.8	.8	1.4	2.3	3.2	1.4	2.5	4.2	5.9	17.1	26.4	42.7	62.9
18	7.1	10.7	17.2	25.5	.5	.9	1.5	2.1	1.5	2.6	4.3	6.0	9.1	14.2	23.0	33.6
Subtotal E	22.0	33.2	53.4	79.3	1.3	2.3	3.8	5.3	2.9	5.1	8.5	11.9	26.2	40.6	65.7	96.5
Subregion F																
19	13.2	19.8	32.0	47.4	.7	1.2	2.1	2.9	1.5	2.7	4.5	6.3	15.4	23.7	38.6	56.6
20	1.2	1.8	3.0	4.4	.2	.4	.6	.8	.5	1.0	1.6	2.2	1.9	3.2	5.2	7.4
21	6.2	9.4	15.0	22.3	.4	.8	1.2	1.8	1.1	2.0	3.4	4.7	7.7	12.2	19.6	28.8
Subtotal F	20.6	31.0	50.0	74.1	1.3	2.4	3.9	5.5	3.1	5.7	9.5	13.2	25.0	39.1	63.4	92.8
REGION TOTAL	172.0	259.1	417.4	619.7	6.6	11.7	19.6	27.1	17.2	30.3	50.6	70.6	195.8	301.1	487.6	717.4

1/ Less than 50 acre-feet.

TABLE I - 11

GOLF COURSE ACREAGES, PRESENT AND PROJECTED

Subregion and Area	1967				Acreage Irrigated					
					1967			1980	2000	2020
	Fairways	Tees and Greens	Rough	Total	Fairways	Tees and Greens	Total	Fairways, Tees and Greens		
Subregion A										
1	150	1/	350	500	1/	1/	1/	200	300	450
2	200	1/	500	700	50	1/	50	300	400	600
3	300	1/	700	1,000	0	1/	1/	400	600	900
4	400	50	950	1,400	100	50	150	650	900	1,400
5	450	50	1,100	1,600	50	1/	50	700	1,000	1,550
Subtotal A	1,500	100	3,600	5,200	200	50	250	2,250	3,200	4,900
Subregion B										
6	1,250	100	2,750	4,100	400	100	500	1,900	2,750	4,150
7	3,450	200	7,650	11,300	2,250	200	2,450	5,100	7,400	11,250
8	4,250	300	9,250	13,800	1,700	250	1,950	6,350	9,250	14,000
9	6,800	450	14,850	22,100	3,750	400	4,150	10,100	14,750	22,300
10	4,450	300	9,650	14,400	1,950	300	2,250	6,600	9,650	14,600
Subtotal B	20,200	1,350	44,150	65,700	10,050	1,250	11,300	30,050	43,800	66,300
Subregion C										
11	1,800	100	4,100	6,000	250	100	350	2,650	3,850	5,850
12	5,100	350	11,350	16,800	1,750	350	2,100	7,600	11,050	16,750
13	7,300	500	15,300	23,100	5,650	450	6,100	10,850	15,850	24,000
Subtotal C	14,200	950	30,750	45,900	7,650	900	8,550	21,100	30,750	46,600
Subregion D										
14	4,550	300	9,650	14,500	2,950	300	3,250	6,750	9,850	14,900
15	10,800	700	23,300	34,800	5,500	700	6,200	16,000	23,350	35,400
16	1,550	100	3,250	4,900	1,150	100	1,250	2,300	3,350	5,100
Subtotal D	16,900	1,100	36,200	54,200	9,600	1,100	10,700	25,050	36,550	55,400
Subregion E										
17	6,100	400	13,300	19,800	2,250	350	2,600	9,050	13,200	20,000
18	2,900	200	6,200	9,300	1,550	200	1,750	4,300	6,300	9,550
Subtotal E	9,000	600	19,500	29,100	3,800	550	4,350	13,350	19,500	29,550
Subregion F										
19	5,350	350	11,500	17,200	2,200	350	2,550	7,950	11,600	17,550
20	500	50	1,150	1,700	100	50	150	750	1,100	1,700
21	2,500	150	5,450	8,100	800	150	950	3,700	5,400	8,150
Subtotal F	8,350	550	18,100	27,000	3,100	550	3,650	12,400	18,100	27,400
REGION TOTAL	70,150	4,650	152,300	227,100	34,400	4,400	38,800	104,200	151,900	230,150

1/ Less than 25

TABLE I-12
GROSS SEASONAL AGRICULTURAL IRRIGATION REQUIREMENTS
FOR HIGH VALUE CROPS 1/
1964, 1980, 2000 and 2020

Subregion and Area	1964	1980	2000	2020
	Acre Feet			
Subregion A				
1	300	20,500	40,000	73,000
2	600	600	1,200	3,200
3	100	200	800	2,200
4	600	1,500	2,300	2,900
5	600	800	1,900	2,500
Subtotal A	2,200	23,600	46,200	83,800
Subregion B				
6	2,600	3,100	3,200	3,200
7	5,700	5,300	4,100	1,800
8	13,800	24,100	14,000	8,200
9	23,600	30,700	21,200	21,200
10	5,600	8,400	4,300	2,200
Subtotal B	51,300	71,600	46,800	36,600
Subregion C				
11	1,300	2,000	2,600	2,600
12	18,900	27,700	34,000	34,000
13	37,300	14,800	-	-
Subtotal C	57,500	44,500	36,600	36,600
Subregion D				
14	8,400	9,400	5,700	3,400
15	86,800	121,000	142,500	107,600
16	28,500	44,700	44,700	44,700
Subtotal D	123,700	175,100	192,900	155,700
Subregion E				
17	20,900	44,800	56,500	68,900
18	27,300	53,500	81,900	81,900
Subtotal E	48,200	98,300	138,400	150,800
Subregion F				
19	15,900	38,700	55,100	48,500
20	2,100	2,400	2,400	2,400
21	4,700	6,400	6,800	6,500
Subtotal F	22,700	47,500	64,300	57,400
REGION TOTAL	305,600	460,600	525,200	520,900

1/ Water to be applied on acreages shown in Table I-8 with crop distribution shown in Table I-5.

TABLE I - 13

MONTHLY DISTRIBUTION OF GROSS SEASONAL AGRICULTURAL IRRIGATION REQUIREMENTS IN PERCENTAGE

Subregion and Area	May	June	July	Aug.	Sept.	Total
Subregion A						
1	-	-	46.7	53.3	-	100.0
2	-	-	45.0	55.0	-	100.0
3	-	10.0	60.0	30.0	-	100.0
4	1.7	10.0	48.3	38.3	1.7	100.0
5	6.7	23.3	43.3	26.7	-	100.0
Subtotal A	2.3	9.5	46.4	41.3	.5	100.0
Subregion B						
6	3.1	13.9	43.8	35.4	3.8	100.0
7	1.4	20.0	50.0	26.5	2.1	100.0
8	1.6	26.0	52.2	18.0	2.2	100.0
9	11.0	23.1	38.9	22.3	4.7	100.0
10	1.8	36.6	37.1	9.5	15.0	100.0
Subtotal B	6.0	24.5	43.8	20.9	4.8	100.0
Subregion C						
11	-	23.8	41.6	33.8	0.8	100.0
12	4.4	33.6	38.8	20.2	3.0	100.0
13	0.4	9.5	42.3	38.3	9.5	100.0
Subtotal C	1.7	17.7	41.3	32.2	7.1	100.0
Subregion D						
14	2.3	26.2	45.1	25.6	0.8	100.0
15	6.8	33.5	34.9	21.2	3.6	100.0
16	11.3	7.2	57.0	20.0	4.5	100.0
Subtotal D	7.5	27.0	40.7	21.2	3.6	100.0
Subregion E						
17	4.9	21.7	42.8	30.6	-	100.0
18	7.7	36.8	30.5	21.8	3.2	100.0
Subtotal E	6.5	30.3	35.8	25.6	1.8	100.0
Subregion F						
19	3.1	24.0	41.2	27.6	4.1	100.0
20	3.8	22.8	36.2	35.2	2.0	100.0
21	6.2	32.1	36.4	21.9	3.4	100.0
Subtotal F	3.8	25.6	39.8	27.2	3.7	100.0
REGION TOTAL	5.7	25.1	40.5	24.5	4.2	100.0

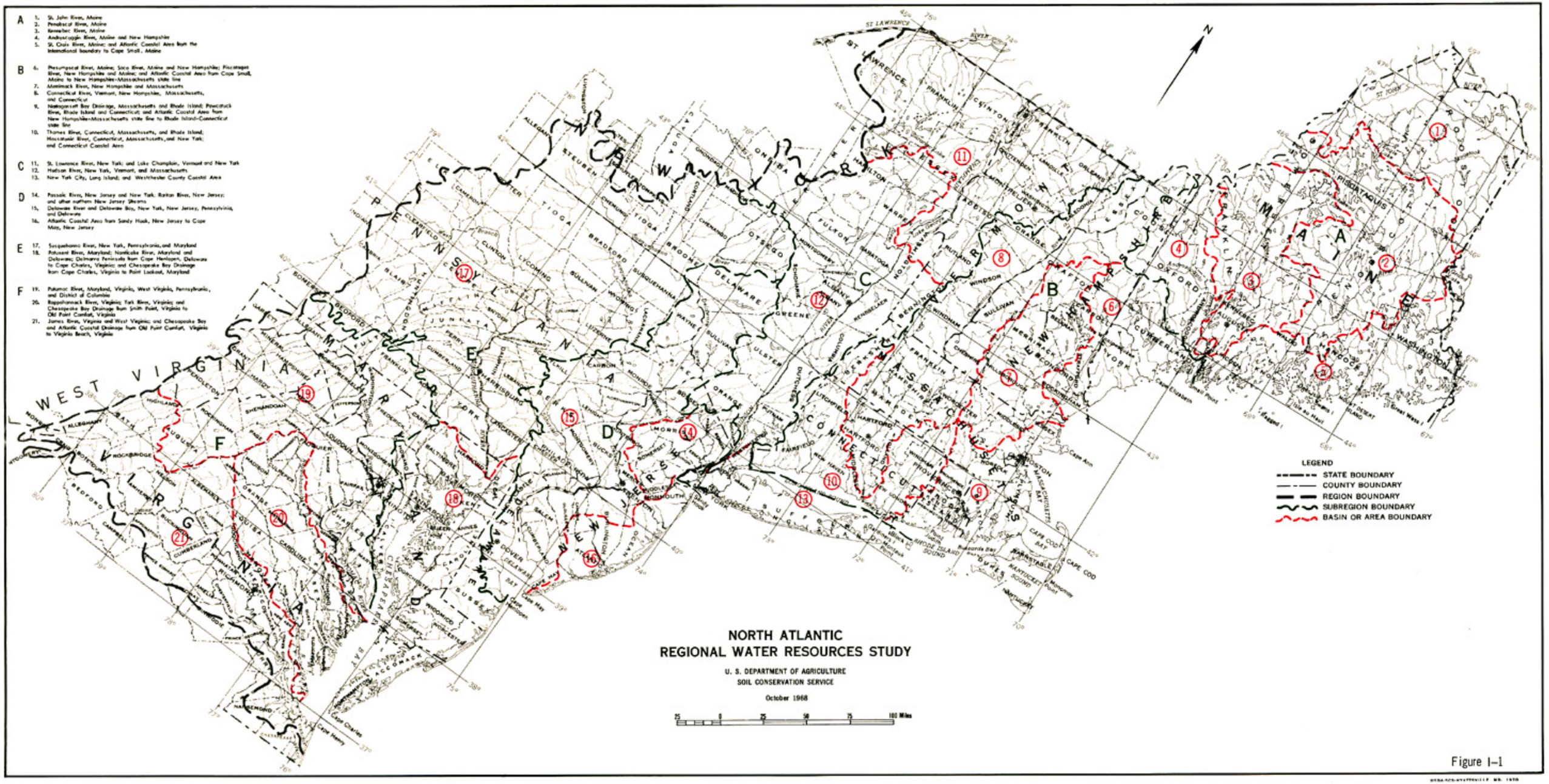
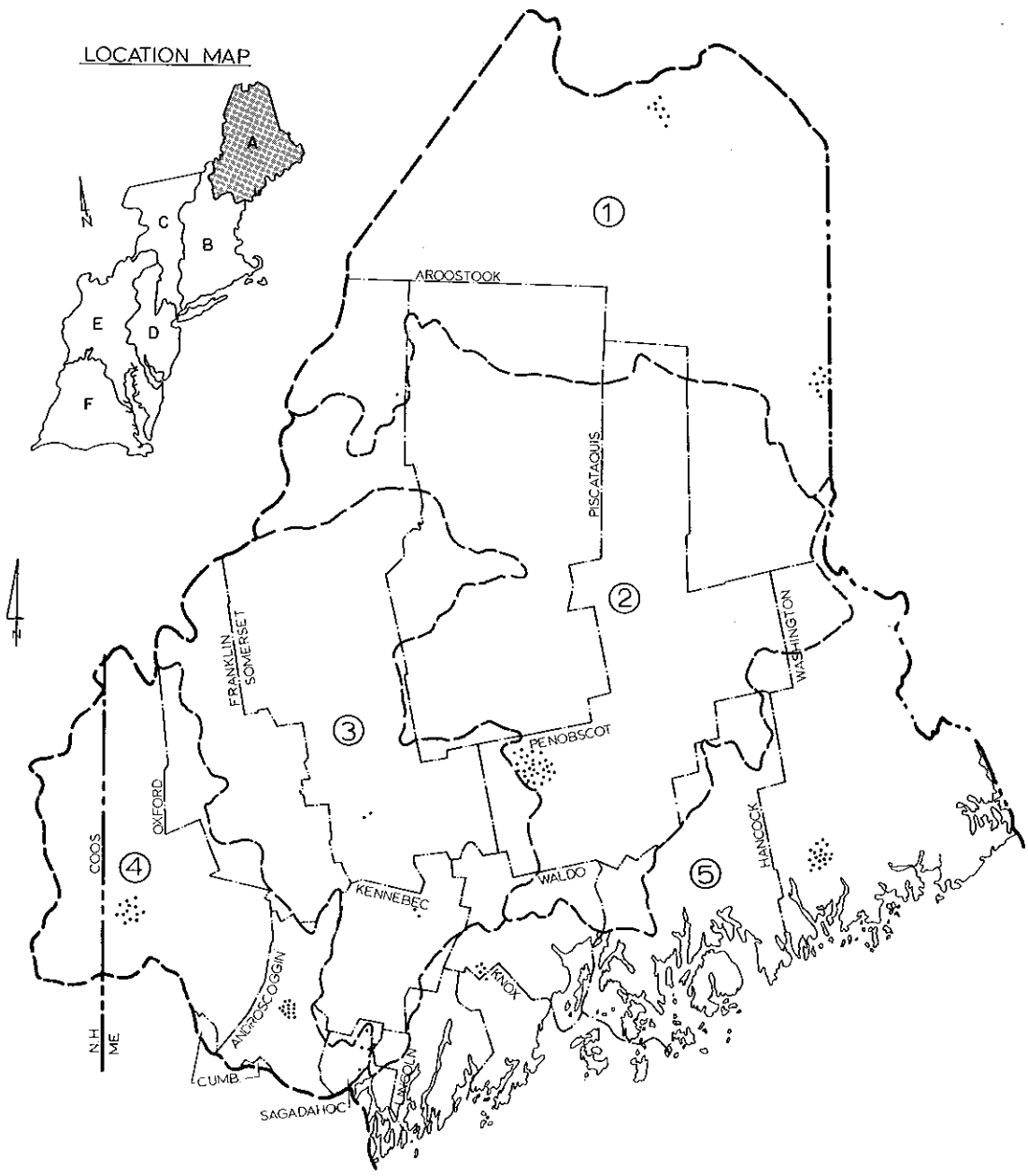

A
1. St. John River, Maine
2. Penobscot River, Maine
3. Kennebec River, Maine
4. Androscoggin River, Maine and New Hampshire
5. St. Croix River, Maine; and Atlantic Coastal Area from the International boundary to Cape Small, Maine
B
6. Presumpscot River, Maine; Saco River, Maine and New Hampshire; Piscataqua River, New Hampshire and Maine; and Atlantic Coastal Area from Cape Small, Maine to New Hampshire-Massachusetts state line
7. Merrimack River, New Hampshire and Massachusetts
8. Connecticut River, Vermont, New Hampshire, Massachusetts, and Connecticut
9. Naumkeag-Nett Bay Drainage, Massachusetts and Rhode Island; Pawcatuck River, Rhode Island and Connecticut; and Atlantic Coastal Area from New Hampshire-Massachusetts state line to Rhode Island-Connecticut state line
10. Thames River, Connecticut, Massachusetts, and Rhode Island; Housatonic River, Connecticut, Massachusetts, and New York; and Connecticut Coastal Area
C
11. St. Lawrence River, New York; and Lake Champlain, Vermont and New York
12. Hudson River, New York, Vermont, and Massachusetts
13. New York City, Long Island; and Westchester County Coastal Area
D
14. Passaic River, New Jersey and New York; Raritan River, New Jersey; and other northern New Jersey Streams
15. Delaware River and Delaware Bay, New York, New Jersey, Pennsylvania, and Delaware
16. Atlantic Coastal Area from Sandy Hook, New Jersey to Cape May, New Jersey
E
17. Susquehanna River, New York, Pennsylvania, and Maryland
18. Patuxent River, Maryland; Nanticoke River, Maryland and Delaware; Delmarva Peninsula from Cape Henlopen, Delaware to Cape Charles, Virginia; and Chesapeake Bay Drainage from Cape Charles, Virginia to Point Lookout, Maryland
F
19. Potomac River, Maryland, Virginia, West Virginia, Pennsylvania, and District of Columbia
20. Rappahannock River, Virginia; York River, Virginia; and Chesapeake Bay Drainage from Smith Point, Virginia to Old Point Comfort, Virginia
21. James River, Virginia and West Virginia; and Chesapeake Bay and Atlantic Coastal Drainage from Old Point Comfort, Virginia to Virginia Beach, Virginia
LEGEND
STATE BOUNDARY
COUNTY BOUNDARY
REGION BOUNDARY
SUBREGION BOUNDARY
BASIN OR AREA BOUNDARY
NORTH ATLANTIC
REGIONAL WATER RESOURCES STUDY
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
October 1968
25 0 25 50 75 100 Miles

Figure I–1



SUB-REGION A

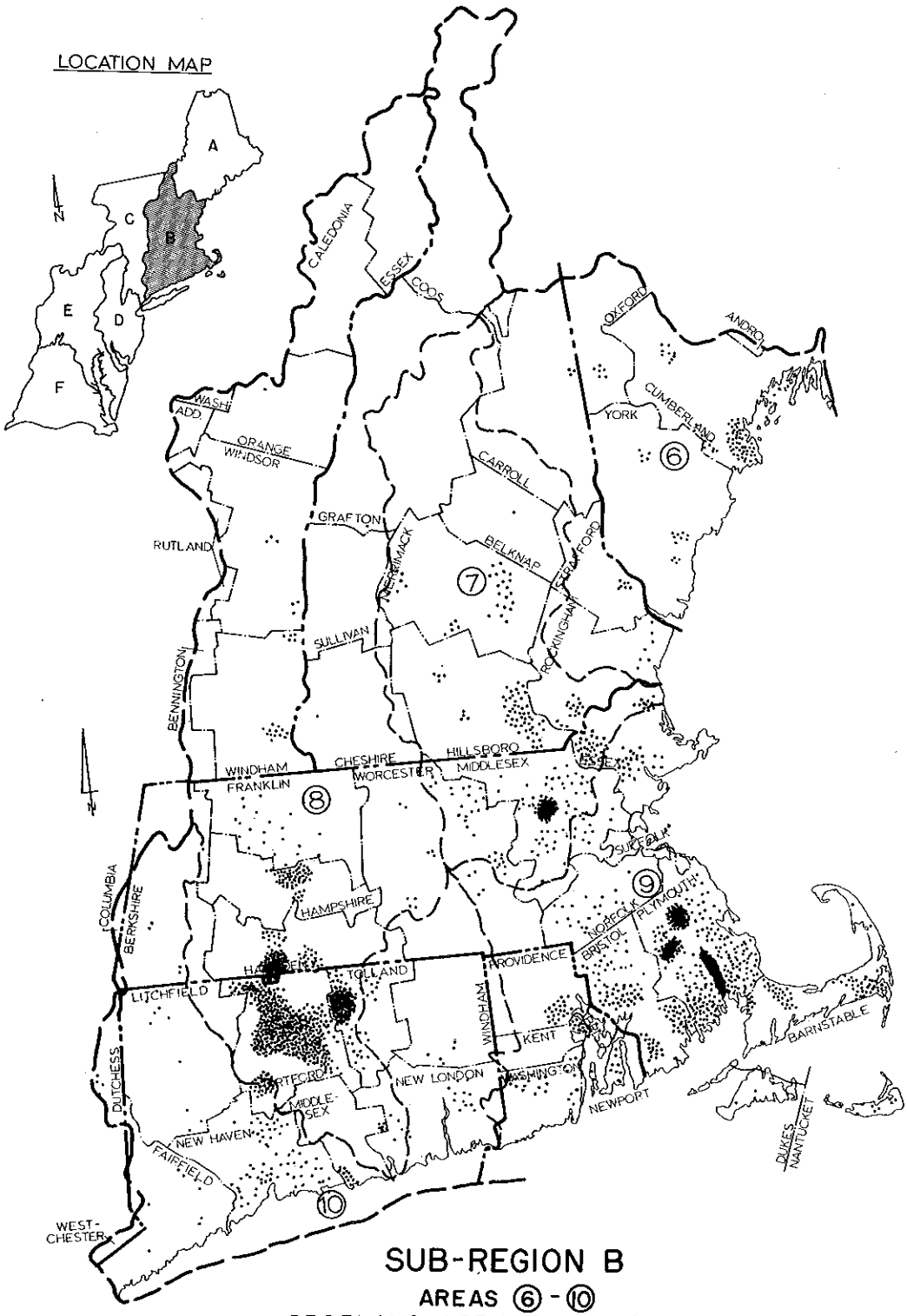
AREAS ① - ⑤

CROPLAND ACREAGE IRRIGATED
1964

1 DOT = 20 ACRES

10 0 10 20 30 40 Miles
SCALE

FIGURE I-2



SUB-REGION B

AREAS ⑥ - ⑩

CROPLAND ACREAGE IRRIGATED

1964

1 DOT = 20 ACRES

10 0 10 20 30 40 Miles

SCALE

FIGURE I-3

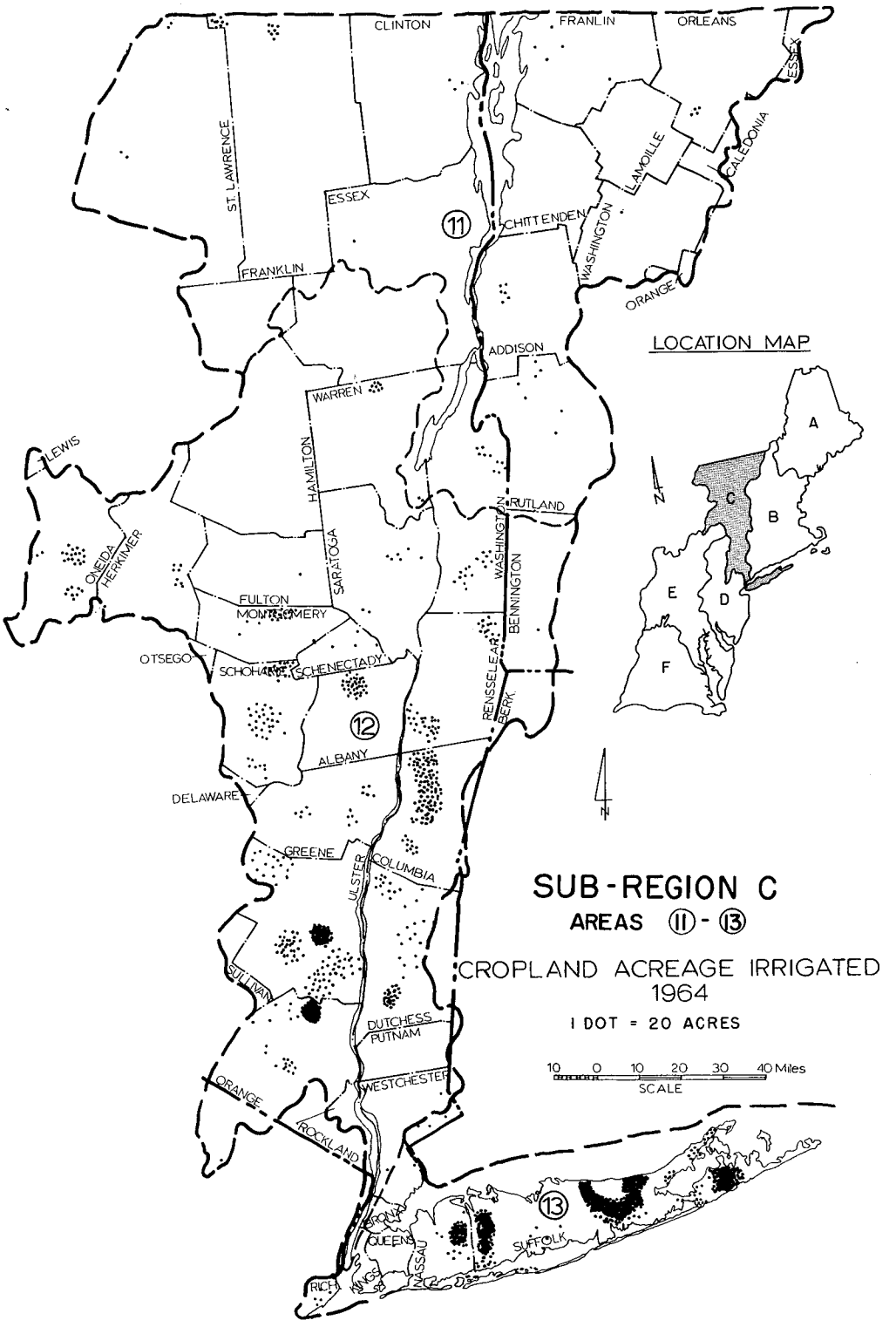
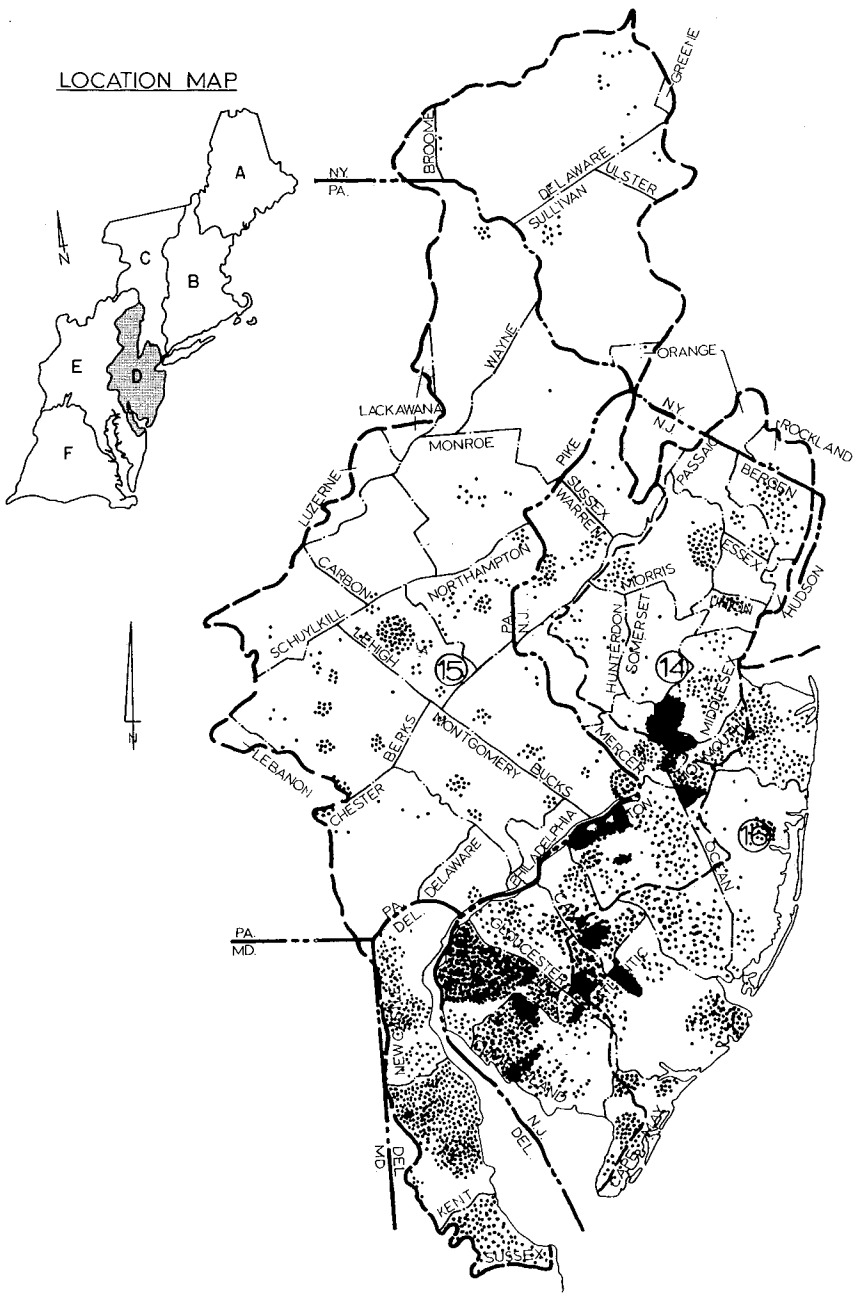

CLINTON
FRANLIN
ORLEANS
ESSEX
ST. LAWRENCE
ESSEX
LAMOILLE
CALEDONIA
11
CHITTENDEN
WASHINGTON
FRANKLIN
ORANGE
ADDISON
WARREN
LEWIS
HAMILTON
RUTLAND
ONEIDA
HERKIMER
SARATOGA
WASHINGTON
FULTON
MONTGOMERY
BENNINGTON
OTSEGO
SCHOHARIE
SCHENECTADY
RENSSELAER
BERK.
12
ALBANY
DELAWARE
GREENE
ULSTER
COLUMBIA
SULLIVAN
DUTCHESS
PUTNAM
ORANGE
WESTCHESTER
ROCKLAND
13
BRONX
QUEENS
NASSAU
SUFFOLK
RICH
KINGS
LOCATION MAP
A
B
C
D
E
F
N
SUB-REGION C
AREAS (11) - (13)
CROPLAND ACREAGE IRRIGATED
1964
1 DOT = 20 ACRES
10 0 10 20 30 40 Miles
SCALE

FIGURE I-4



SUB-REGION D

AREAS (14) - (16)

CROPLAND ACREAGE IRRIGATED

1964

1 DOT = 20 ACRES

10 0 10 20 30 40 Miles

SCALE

FIGURE I-5

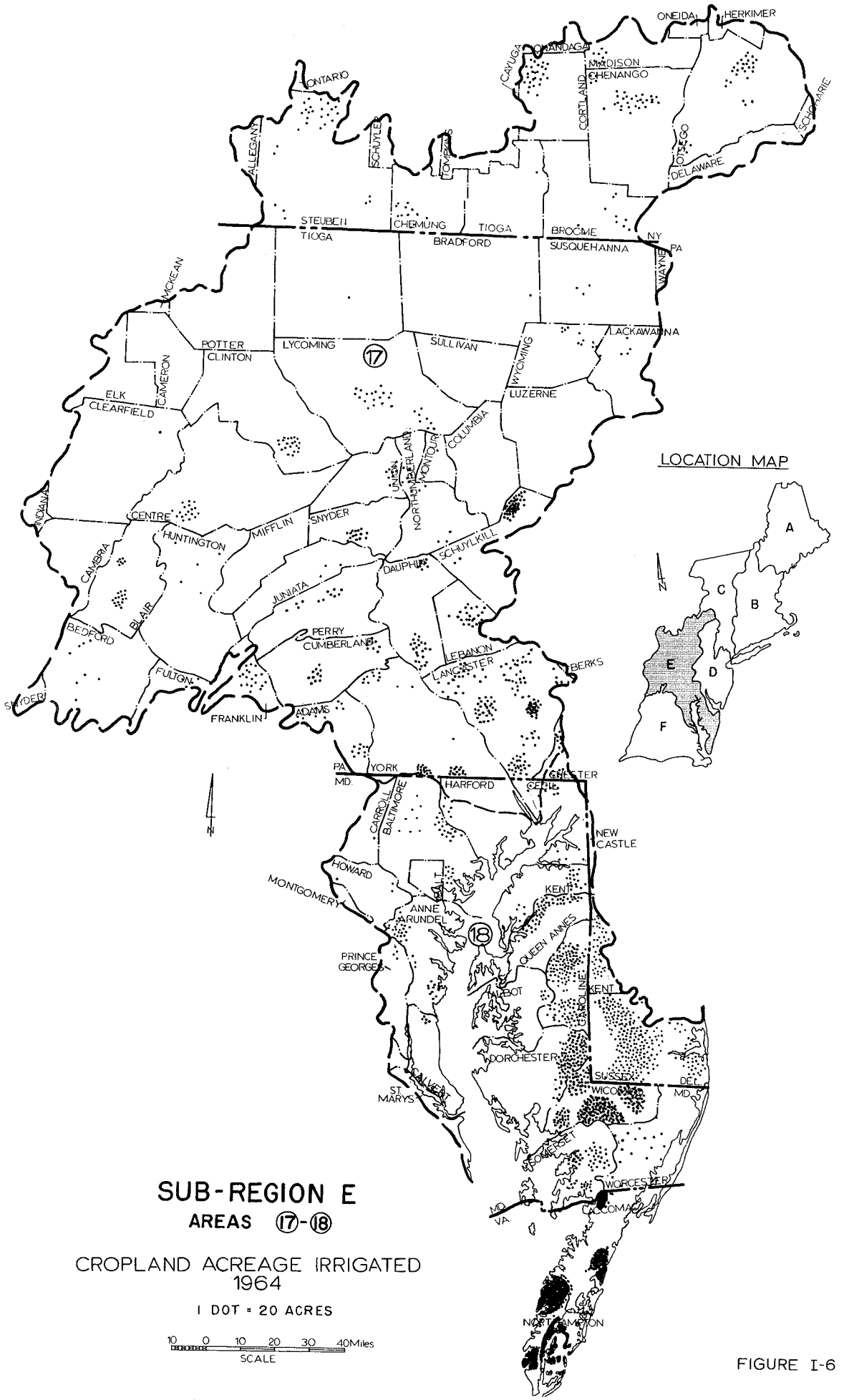
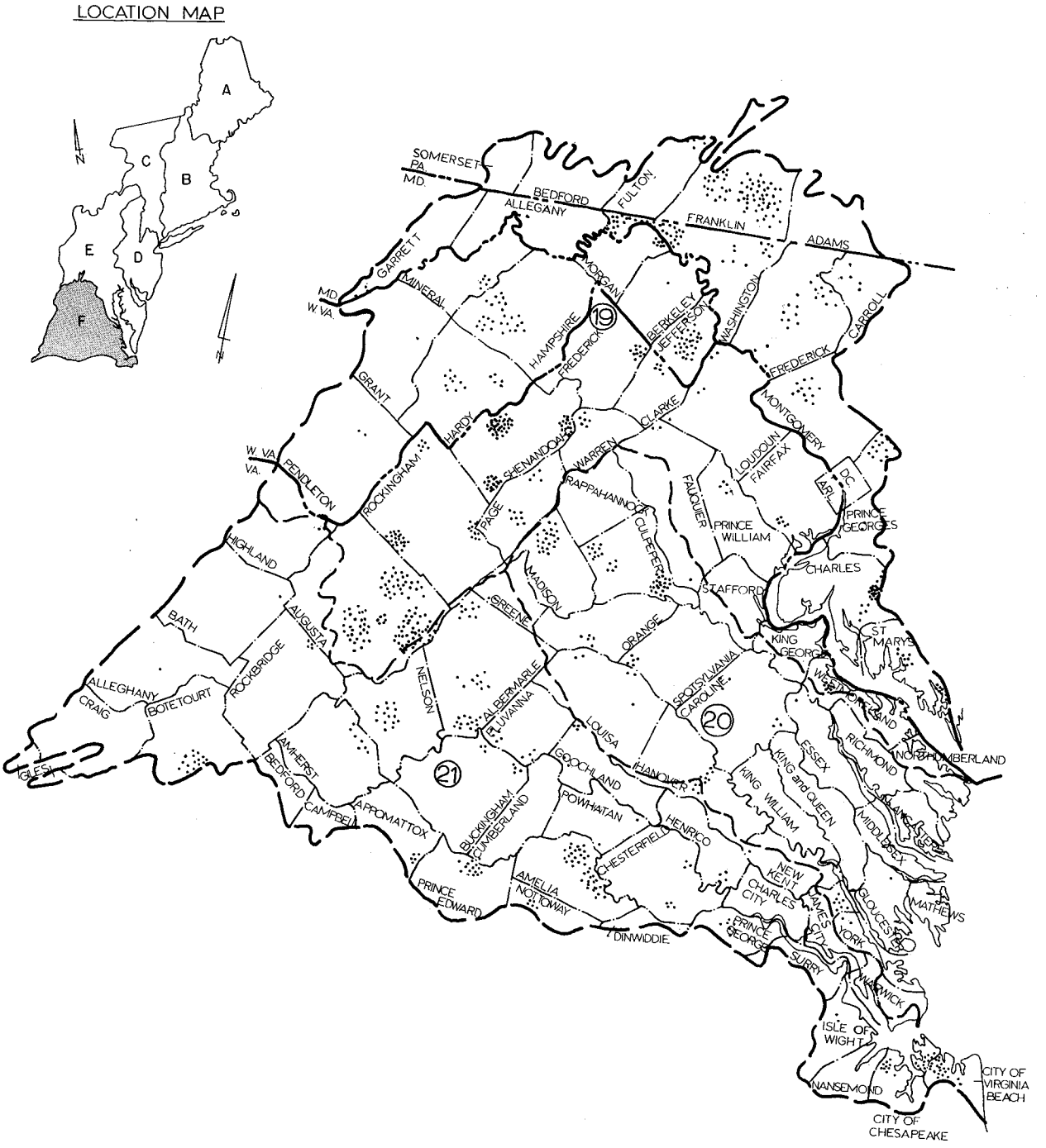

ONEIDA
HERKIMER
CAYUGA
ONONDAGA
MADISON
CHENANGO
CORTLAND
ONTARIO
ALLEGANY
SCHUYLER
TOMPKINS
OTSEGO
SCHOHARIE
DELAWARE
STEUBEN
TIOGA
CHEMUNG
TIOGA
BRADFORD
BROOME
SUSQUEHANNA
NY
PA
WAYNE
MCKEAN
POTTER
CLINTON
LYCOMING
17
SULLIVAN
WYOMING
LACKAWANNA
LUZERNE
ELK
CLEARFIELD
CAMERON
COLUMBIA
MONTOUR
NORTHUMBERLAND
UNION
INDIANA
CENTRE
HUNTINGTON
MIFFLIN
SNYDER
SCHUYLKILL
CAMBRIA
JUNIATA
DAUPHIN
BLAIR
BEDFORD
PERRY
CUMBERLAND
LEBANON
LANCASTER
BERKS
FULTON
SNYDER
FRANKLIN
ADAMS
PA
MD.
YORK
HARFORD
CHESTER
DEL.
CARROLL
BALTIMORE
NEW CASTLE
HOWARD
MONTGOMERY
KENT
ANNE ARUNDEL
18
QUEEN ANNES
PRINCE GEORGES
TALBOT
CAROLINE
KENT
DORCHESTER
SUSSEX
DEL.
WICOMICO
MD.
CALVERT
ST MARYS
SOMERSET
WORCESTER
MD.
VA.
ACCOMACK
NORTHAMPTON
LOCATION MAP
A
B
C
D
E
F
N
SUB-REGION E
AREAS 17-18
CROPLAND ACREAGE IRRIGATED
1964
1 DOT = 20 ACRES
10 0 10 20 30 40Miles
SCALE

FIGURE I-6



SUB-REGION F

AREAS (19) - (21)

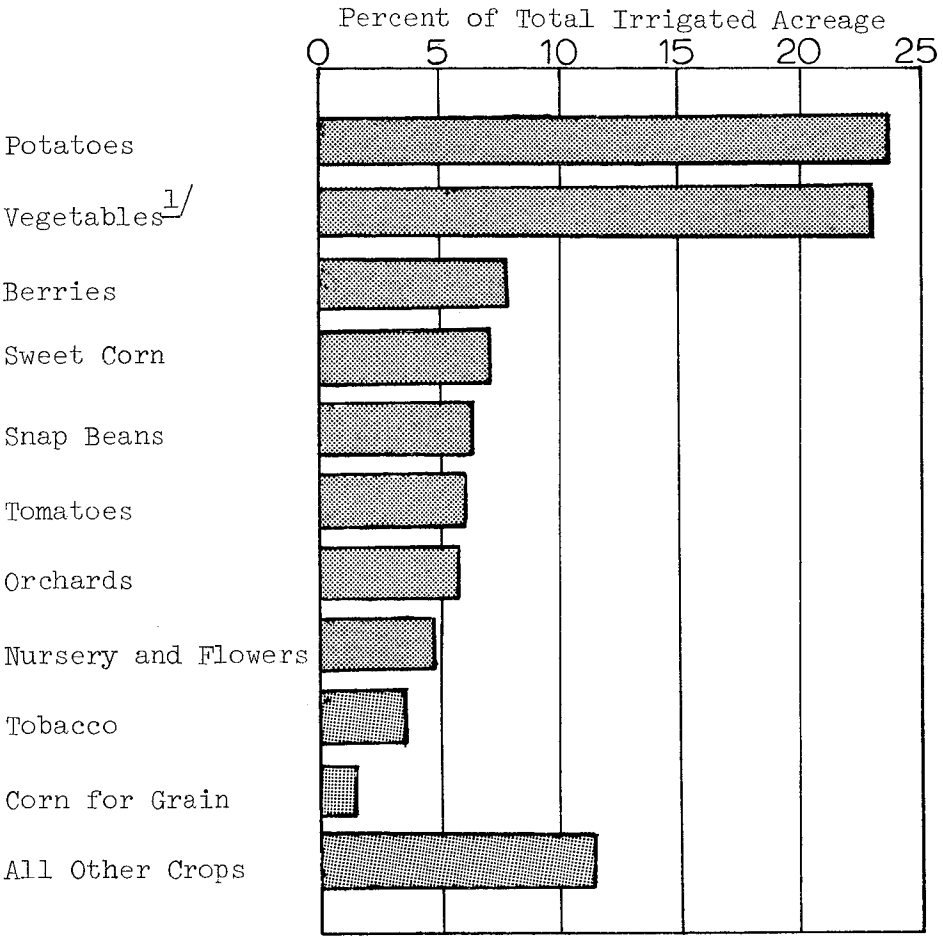
CROPLAND ACREAGE IRRIGATED
1964

1 DOT = 20 ACRES

10 0 10 20 30 40 Miles
SCALE

FIGURE I-7

DISTRIBUTION OF ACREAGE IRRIGATED IN 1964, BY PRINCIPAL CROPS, FOR THE NORTH ATLANTIC REGION



Source: U.S. Census of Agriculture

1/ Excludes sweet corn, snap beans and tomatoes

FIGURE I - 8

ESTIMATED NAR PRODUCTION AS A PERCENTAGE OF NAR PRODUCT REQUIREMENTS, 1959 - 1960

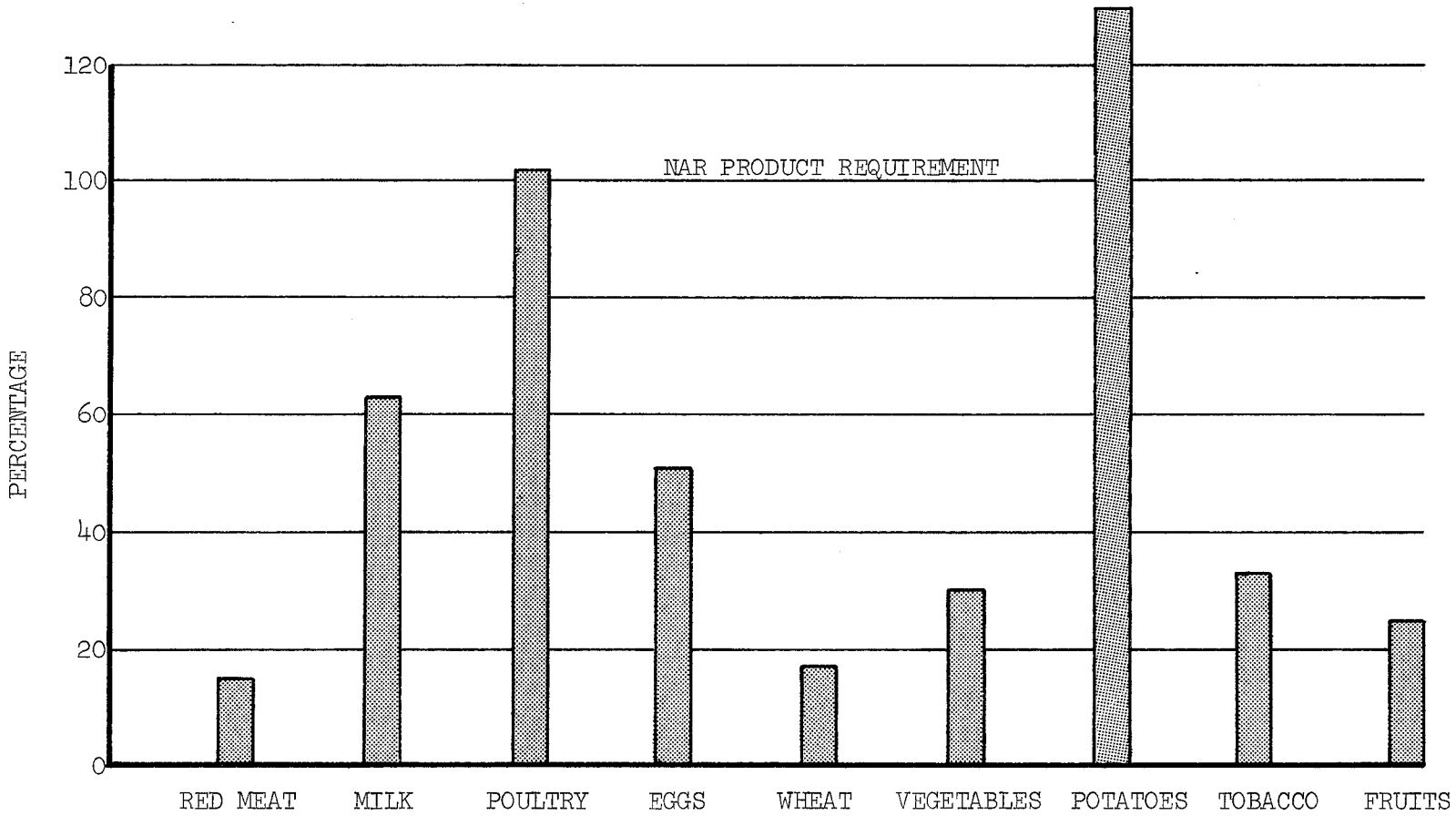
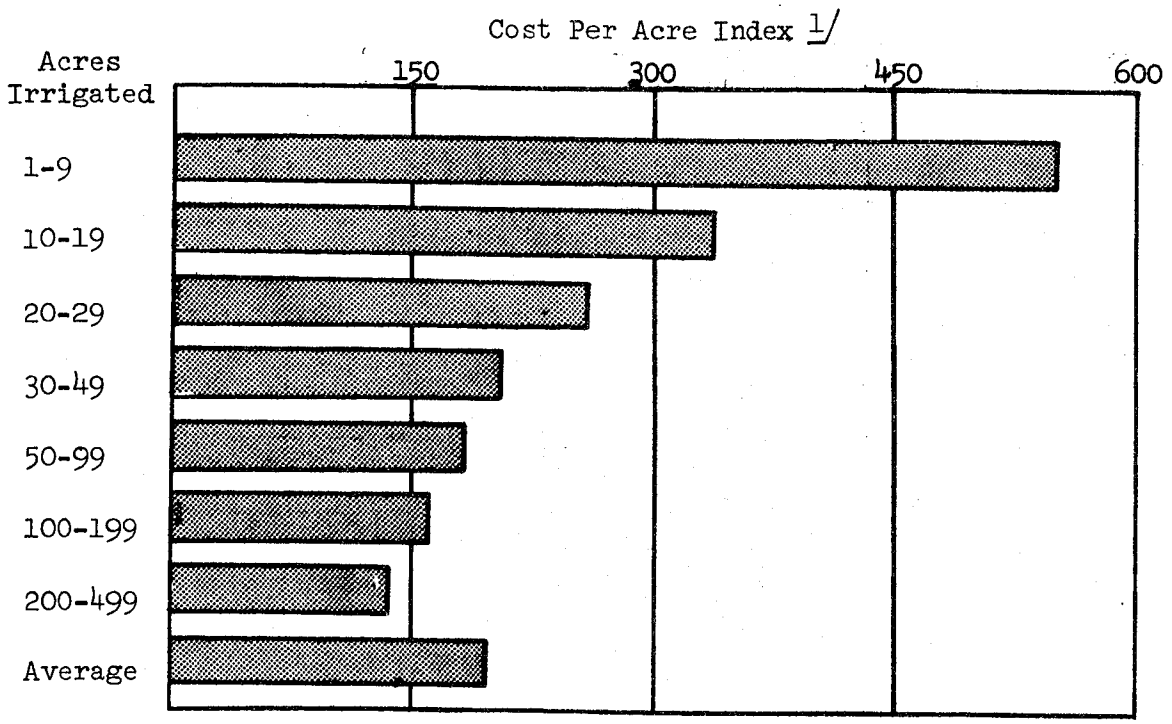


FIGURE I - 9

TOTAL COST OF IRRIGATION SYSTEMS PER ACRE IRRIGATED,
FOR FARMS CLASSIFIED BY ACREAGE IRRIGATED
FOR THE NORTH ATLANTIC REGION



Source: U.S. Census of Agriculture: 1954, Vol. III, Special Reports Part 6, Irrigation in Humid Areas(Washington, D.C., 1956)

1/ Index = 1970 Dollars
(updated using wholesale price of agricultural machinery and equipment)

FIGURE I - 10

MONTHLY DISTRIBUTION OF GROSS SEASONAL
IRRIGATION REQUIREMENTS BY SUBREGION AND REGION, 1964

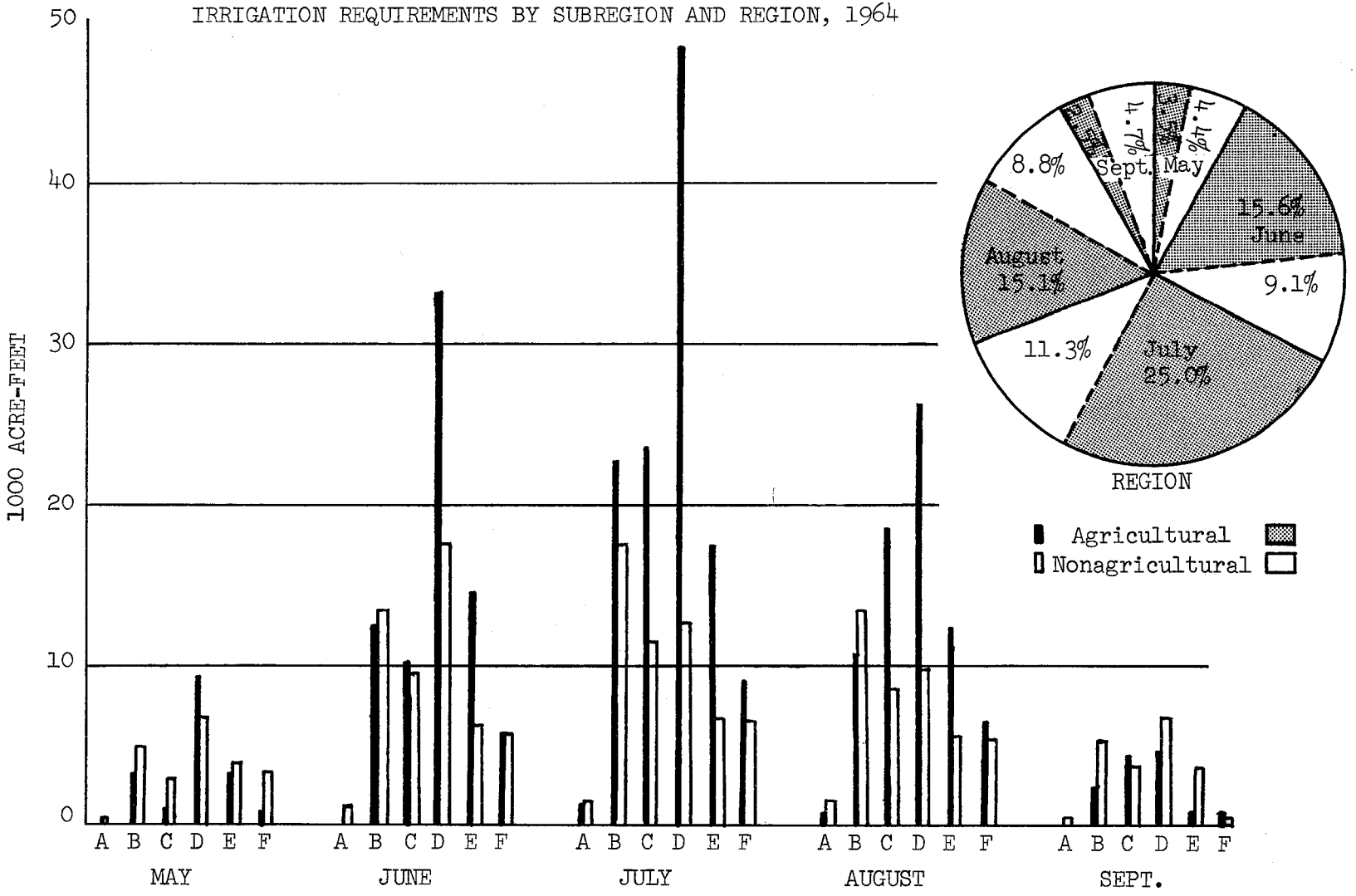


FIGURE I - 11

EXHIBIT I

CLUSTER ANALYSIS FOR URBAN COUNTIES

IN THE NORTH ATLANTIC REGION

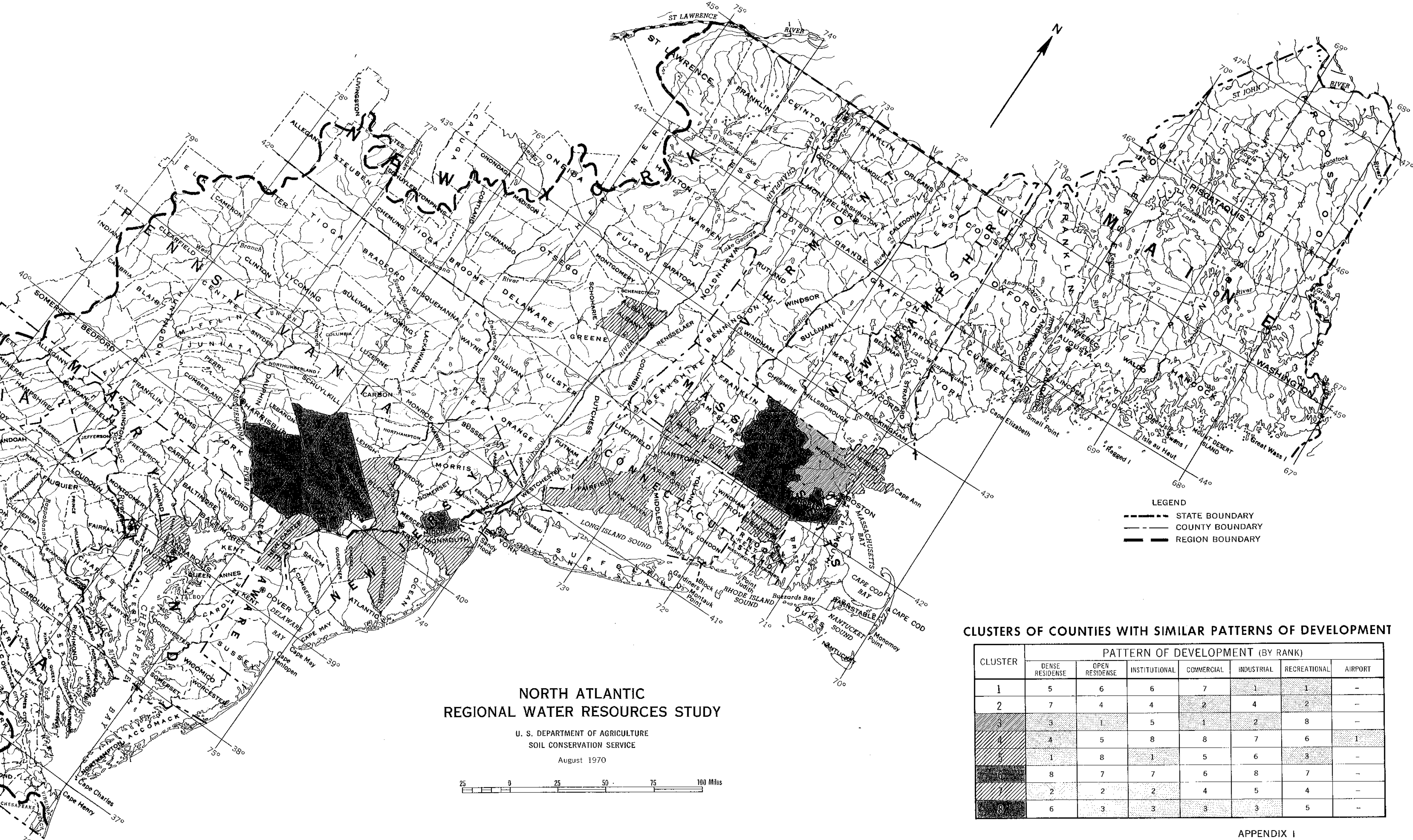
VARIABLES USED TO CLUSTER RURAL TO URBAN COUNTIES IN NAR

Fifteen variables were used to group selected counties exhibiting similar growth characteristics into clusters.

1. New housing units authorized - 1966.
2. Gross assessed property value - change 1956 - 1961.
3. Percent urban land is of total land - 1966.
4. Value added by manufacturing - change 1954 - 1963.
5. Population density per square mile - change 1950 - 1960.
6. Median family income - change 1950 - 1960.
7. Per acre sales of farm products - 1954 - 1964.
8. Population change - 1950 - 1960.
9. Total Net Migration - change 1950 - 1960.
10. Rate (acres) of urbanization - increase 1958 - 1966.
11. Retail employment - change 1956 - 1966.
12. Total taxable payroll per capita January - March - change 1956 - 1966.
13. Total employment - 1956 - 1966 (change).
14. Labor force working outside county - 1966.
15. Distance from urban center.

The choice of the number of clusters is facilitated by an evaluation of the total sum of squares (within groups). By computing the difference between these values for successive clusters, the analyst can choose the number of clusters where the most explanation of difference occurs in relation to the total value. Utilizing this choice criterion resulted in the selection of eight clusters of counties exhibiting similar growth characteristics.

Each cluster has a different pattern of development as shown in the legend on the following map.



NORTH ATLANTIC
REGIONAL WATER RESOURCES STUDY

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

August 1970

CLUSTERS OF COUNTIES WITH SIMILAR PATTERNS OF DEVELOPMENT

CLUSTER	PATTERN OF DEVELOPMENT (BY RANK)						
	DENSE RESIDENSE	OPEN RESIDENSE	INSTITUTIONAL	COMMERCIAL	INDUSTRIAL	RECREATIONAL	AIRPORT
1	5	6	6	7	1	1	–
2	7	4	4	2	4	2	–
3	3	1	5	1	2	8	–
4	4	5	8	8	7	6	1
5	1	8	1	5	6	3	–
6	8	7	7	6	8	7	–
7	2	2	2	4	5	4	–
8	6	3	3	3	3	5	–

APPENDIX I

USDA-SCS-HYATTSVILLE, MD. 1970

EXHIBIT II

DATA USED IN PLAN FORMULATION

OF THE NORTH ATLANTIC REGION

1. Acreage Considered for Irrigation (Total)

   a. Total cropland projections for each NAR area based on historical trends given in Appendix G, Land Use and Management. The specialized crops, field corn, and other cropland are constrained by the total cropland projections.

   b. The methodologies and assumptions for projections of agricultural acreages are explained in the Appendix on pages I-5 and I-6.

2. Irrigation Demands for Land (Incremental)

   a. Cropland

      (1) National Efficiency (NE). These acreages are based on historical trends and are taken from Table I-8 in the Appendix.

      (2) Regional Development (RD). In addition to the high value crops (NE) it was assumed that there will be irrigation of marginal crops in order to increase income to rural areas. Crops that are considered marginal to irrigate are medium value crops and include field corn (corn silage and corn grain) and alfalfa. It was assumed that field corn would be irrigated sooner than alfalfa. By 1980, 30 percent of the field corn and 15 percent of the alfalfa are expected to be irrigated. By 2000 all of the field corn and 50 percent of the alfalfa are expected to be irrigated. By 2020, (a) all of the 2000 field corn or all of the 2020 field corn will be irrigated, whichever is smaller; and (b) the 2000 irrigated acreage for all alfalfa will be irrigated.

      (3) Environmental Quality (EQ). The EQ acreage is the same as RD except in 2020. By 2020, (a) all the 2000 field corn or all the 2020 field corn will be irrigated, whichever is larger; and (b) the 2000 irrigated acreage for alfalfa or 60 percent of the 2020 acreage of alfalfa will be irrigated, whichever is larger.

   b. Golf Course. Golf course projected acreages were based on historical trends. The acreages shown are the fairways, and tees and greens. The fairways, tees and greens are usually irrigated which is about 30 percent of the acreage of a golf course. For more detail refer to the Appendix on page I-12. The acreages were assumed to be the same for all three objectives for the corresponding target year.

   c. Industrial and Institutional. Industrial and Institutional greenery projections are based on cluster analysis and aerial

photo interpretations. For further detail refer to pages I-11 and I-12 in the appendix.

Under NE for the target years 1980, 2000 and 2020, 20 percent, 60 percent, and 100 percent respectively of industrial and institutional lawns are expected to be irrigated. Under RD for the target years 1980, 2000 and 2020, 40 percent, 80 percent, and 100 percent respectively of the industrial and institutional lawns are expected to be irrigated. Under EQ, 100 percent of the industrial and institutional lawns are expected to be irrigated in 1980, 2000 and 2020.

3. Irrigation Demands for Water

   a. Cropland. Crop irrigation water requirements in inches are shown in the Appendix in Table I-9. These requirements were applied to the cropland acreage to arrive at the water requirements in acre feet.

   b. Golf courses. It was assumed that the seasonal water requirement was 26 inches and 25 inches for fairways, and tees and greens respectively. These requirements were applied to the golf course acreage to arrive at the water requirement in acre feet.

   c. Industrial and Institutional. It was assumed that the season water requirement was applied to the industrial and institutional acreage to arrive at the water requirement in acre feet.

4. Cost

   a. One Time. The calculated one time cost is $325 per acre for agricultural, and industrial and institutional irrigation systems, and $2000 per irrigated acre for golf course irrigation systems.

   b. Average Annual. The average annual cost for agricultural, and industrial and institutional irrigation is $60 per acre. The average annual cost for golf course irrigation is $200 per acre.

5. Benefits Toward Each Objective

   a. National Efficiency. On the basis of experience B:C ratios of 2:1 for High Value Crops and for Marginal Crops were used. For purpose of calculations B:C ratios of 2:1 for Golf and 1:1 for Industrial and Institutional were used. Applying these B:C ratios to the average annual cost per acre, we calculated average annual benefits of $120 per acre for high value crops; $400 per acre for golf; $60 per acre for marginal crops; and $60 per acre for Industrial

and Institutional. The total average annual was calculated by multiplying these values by the incremental acreages.

b. Regional Development. RD benefits that result from increased spending by project beneficiaries (multiplier income) are estimated to be 20 percent of NE benefits. Otherwise underutilized and attracted resources used in construction and operation are estimated at 25 percent of the average annual cost. Depending on charges imposed on users, up to 100 percent of the NE benefits may be added.

c. Environmental Quality. EQ benefits while not measured in monetary terms could be thought of in terms of percent of total irrigated land to the total areas of the basin. Irrigation contributed to profitable agriculture and visual quality thus helping to maintain farm character and open space. A study of the NAR's visual quality (see Appendix G - Land Use and Management) indicates that an additional 745,000 water surface acres are needed to achieve a desirable level of visual quality. Nearly all of this water surface acreage is needed in Areas 14 through 21. Water projects constructed in these Areas could accrue benefits to the environmental account as well as increasing irrigation water supply.

SUBREGION A - AREA 1

Irrigable soils comprise 23% of the Area's 4710 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25% of the agricultural water comes from ground water and 75% from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	70.0	2.2	124.8	.1	.2
2000	70.0	1.0	62.0	.1	.4
2020	70.0	.2	11.8	.1	.6

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $)	RD Mill.	EQ % Land
	1966	.3	0	0	.1	0	0					
NATIONAL EFFICIENCY												
	1980	20.2	.2	0	20.4	.5	0	7.0	1.3	2.5	.8	.4
	2000	22.8	.2	.1	19.5	.4	.1	7.9	1.4	2.8	.9	.5
	2020	33.8	.2	0	33.0	.4	0	11.4	2.1	4.1	1.3	.7
REGIONAL DEVELOPMENT												
	1980	32.2	.2	0	38.0	.5	0	10.9	2.0	3.2	1.1	.7
	2000	64.9	.2	.1	74.6	.4	.1	21.5	3.9	5.4	2.1	1.4
	2020	33.0	.2	0	32.1	.4	0	11.1	2.0	4.1	1.3	.7
ENVIRONMENTAL QUALITY												
	1980	32.2	.2	0	38.0	.5	0	10.9	2.0	3.2	1.1	.7
	2000	64.9	.2	.1	64.9	.4	.1	21.5	3.9	5.4	2.1	1.4
	2020	33.8	.2	0	33.0	.4	0	11.4	2.1	4.1	1.3	.7

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION A - AREA 2

Irrigable soils comprise 7% of the Area's 5456 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25% of the agricultural water comes from ground water and 75% from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	4.6	3.7	57.7	.1	.3
2000	4.1	3.7	22.2	.2	.5
2020	3.5	5.4	6.1	.3	.7

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	.7	.1	0	.3	.1	0					
NATIONAL EFFICIENCY												
	1980	0	.2	0	.3	.6	0	.4	.1	.1	.1	<.1
	2000	.7	.2	.2	.6	.5	.2	.7	.1	.2	.1	<.1
	2020	2.5	.2	.1	2.0	.5	.1	1.2	.2	.4	.1	.1
REGIONAL DEVELOPMENT												
	1980	2.1	.2	0	3.4	.6	0	1.1	.2	.2	.1	.1
	2000	6.4	.2	.2	8.8	.5	.2	2.5	.4	.5	.2	.1
	2020	2.5	.2	.1	2.0	.5	.1	1.2	.2	.4	.1	.1
ENVIRONMENTAL QUALITY												
	1980	2.1	.2	.1	3.4	.6	.1	1.1	.2	.2	.1	.1
	2000	6.4	.2	.2	8.8	.5	.2	2.5	.4	.5	.2	.1
	2020	5.1	.2	0	5.7	.5	0	2.1	.3	.5	.2	.1

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION A - AREA 3

Irrigable soils comprise 15% of the Area's 3757 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25 % of the agricultural water comes from ground water and 75 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	3.4	6.2	87.4	.2	.5
2000	2.9	6.8	44.3	.3	.8
2020	2.4	6.0	20.6	.4	1.1

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ % Land
	1966	.1	0	0	.1	0	0					
NATIONAL EFFICIENCY												
	1980	.2	.5	0	.1	1.1	0	1.1	.1	.2	.1	<.1
	2000	.7	.3	.2	.6	.7	.2	.9	.1	.2	.1	<.1
	2020	1.7	.3	.2	1.4	.8	.2	1.2	.2	.3	.1	.1
REGIONAL DEVELOPMENT												
	1980	4.0	.5	.1	5.7	1.1	.1	2.3	.3	.4	.2	.1
	2000	10.1	.3	.1	14.3	.7	.1	3.9	.7	.8	.3	.3
	2020	1.7	.3	.2	1.4	.8	.2	1.2	.2	.3	.1	.1
ENVIRONMENTAL QUALITY												
	1980	4.0	.5	.2	5.7	1.1	.2	2.4	.4	.5	.2	.1
	2000	10.1	.3	.1	14.3	.7	.1	3.9	.7	.8	.3	.3
	2020	4.9	.3	.1	5.6	.8	.1	2.2	.4	.5	.2	.1

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION A - AREA 4

Irrigable soils comprise 17% of the Area's 2208 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25 % of the agricultural water comes from ground water and 75 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	3.9	5.1	55.0	.1	.7
2000	3.4	5.4	27.2	.2	1.1
2020	2.9	7.5	10.6	.3	1.6

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	.7	.2	0	.3	.4	0					
NATIONAL EFFICIENCY												
	1980	.9	.5	0	1.2	1.1	0	1.3	.2	.3	.1	.1
	2000	.9	.4	.2	.8	1.0	.2	1.2	.1	.3	.1	.1
	2020	.7	.5	.1	.6	1.2	.1	1.3	.1	.3	.1	.1
REGIONAL DEVELOPMENT												
	1980	3.7	.5	0	5.4	1.1	0	2.2	.3	.5	.2	.2
	2000	8.1	.4	.2	11.4	1.0	.2	3.5	.6	.7	.3	.4
	2020	.7	.5	.1	.6	1.2	.1	1.3	.1	.3	.1	.1
ENVIRONMENTAL QUALITY												
	1980	3.7	.5	.1	5.4	1.1	.1	2.2	.3	.5	.2	.2
	2000	8.1	.4	.2	11.4	1.0	.2	3.5	.6	.7	.3	.4
	2020	3.4	.5	0	4.4	1.2	0	2.1	.3	.4	.2	.2

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION A - AREA 5

Irrigable soils comprise 20% of the Area's 3988 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25 % of the agricultural water comes from ground water and 75 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	3.1	8.7	51.2	.4	.7
2000	2.6	9.0	43.4	.7	1.1
2020	2.3	12.3	16.4	1.0	1.7

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ % Land
	1966	.6	.1	0	.3	.1	0					
NATIONAL EFFICIENCY												
	1980	.2	.6	.1	.5	1.5	.1	1.3	.1	.3	.1	<.1
	2000	1.1	.4	.3	1.1	1.0	.3	1.3	.2	.3	.1	.1
	2020	.6	.6	.6	.6	1.3	.6	1.6	.2	.3	.1	.1
REGIONAL DEVELOPMENT												
	1980	4.3	.6	.2	6.8	1.5	.2	2.7	.4	.5	.2	.1
	2000	11.0	.4	.4	15.9	1.0	.4	4.5	.8	.9	.4	.3
	2020	.6	.6	.4	.6	1.3	.4	1.5	.2	.3	.1	.1
ENVIRONMENTAL QUALITY												
	1980	4.3	.6	.4	6.8	1.5	.4	2.7	.4	.5	.2	.2
	2000	11.0	.4	.3	15.9	1.0	.3	4.5	.8	.9	.4	.3
	2020	4.8	.6	.3	6.7	1.3	.3	2.9	.4	.6	.2	.2

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION B - AREA 6

Irrigable soils comprise 29% of the Area's 2692 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25 % of the agricultural water comes from ground water and 75 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	4.3	3.4	76.3	.9	2.0
2000	2.7	3.7	33.6	1.5	3.2
2020	2.7	5.1	9.2	2.1	4.8

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	2.4	.5	.1	1.3	1.3	.1					
NATIONAL EFFICIENCY												
	1980	.5	1.5	.1	1.8	3.3	.1	3.2	.3	.6	.2	.2
	2000	.1	1.2	.7	.1	2.8	.7	2.7	.3	.5	.2	.2
	2020	0	1.6	1.2	0	3.6	1.2	3.6	.4	.7	.2	.2
REGIONAL DEVELOPMENT												
	1980	2.6	1.5	.3	3.7	3.3	.3	3.9	.5	.8	.3	.3
	2000	5.4	1.2	.8	8.0	2.8	.8	4.4	.6	.8	.3	.4
	2020	0	1.6	.9	0	3.6	.9	3.5	.4	.7	.2	.2
ENVIRONMENTAL QUALITY												
	1980	2.6	1.5	.8	3.7	3.3	.8	4.1	.5	.8	.3	.3
	2000	5.4	1.2	.6	8.0	2.8	.6	4.4	.6	.8	.3	.4
	2020	2.0	1.6	.6	2.9	3.6	.6	4.0	.5	.8	.3	.3

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION B - AREA 7

Irrigable soils comprise 15% of the Area's 3232 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25 % of the agricultural water comes from ground water and 75 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	9.4	3.0	73.6	1.8	5.5
2000	3.7	3.2	30.1	3.0	8.9
2020	1.6	4.5	8.9	4.2	13.2

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	5.7	2.5	.2	2.8	5.7	.2					
NATIONAL EFFICIENCY												
	1980	-.4	3.0	.2	-.4	7.0	.2	6.1	.6	1.2	.4	.3
	2000	-1.2	3.4	1.5	-1.2	7.7	1.5	7.3	.8	1.4	.5	.4
	2020	-2.3	4.3	2.3	-2.3	9.9	2.3	9.3	1.0	1.8	.6	.4
REGIONAL DEVELOPMENT												
	1980	1.4	3.0	.5	1.9	7.0	.5	6.7	.7	1.3	.4	.4
	2000	3.2	3.4	1.8	4.4	7.7	1.8	8.8	1.1	1.7	.6	.5
	2020	-2.3	4.3	1.7	-2.3	9.9	1.7	9.2	1.0	1.8	.6	.4
ENVIRONMENTAL QUALITY												
	1980	1.4	3.0	1.6	1.9	7.0	1.6	7.1	.8	1.4	.5	.4
	2000	3.2	3.4	1.3	4.4	7.7	1.3	8.6	1.0	1.7	.6	.5
	2020	-.5	4.3	1.1	-.2	9.9	1.1	9.5	1.0	1.9	.6	.4

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION B - AREA 8

Irrigable soils comprise 9 % of the Area's 7128 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25 % of the agricultural water comes from ground water and 75 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	22.5	22.0	255.5	2.2	6.8
2000	13.1	23.2	123.7	3.7	11.0
2020	7.6	32.0	44.4	5.2	16.2

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	14.2	1.9	.1	6.9	4.8	.1					
NATIONAL EFFICIENCY												
	1980	10.6	4.9	.3	17.2	10.8	.3	13.3	1.6	3.2	1.0	.4
	2000	-10.4	4.2	1.8	-7.1	9.6	1.8	9.0	.9	2.2	.7	.2
	2020	-6.0	5.2	3.0	-5.8	12.1	3.0	11.4	1.2	2.3	.8	.2
REGIONAL DEVELOPMENT												
	1980	21.5	4.9	.8	31.3	10.8	.8	17.0	2.3	3.9	1.4	.6
	2000	15.5	5.2	2.1	25.8	9.6	2.1	19.5	2.7	3.8	1.4	.5
	2020	-6.0	5.2	2.2	-5.8	12.1	2.2	11.1	1.2	2.2	.7	.2
ENVIRONMENTAL QUALITY												
	1980	21.5	4.9	2.1	31.3	10.8	2.1	17.5	2.4	4.0	1.4	.6
	2000	15.5	4.2	1.5	25.8	9.6	1.5	17.3	2.5	3.3	1.3	.5
	2020	5.6	5.2	1.5	8.1	12.1	1.5	14.6	1.8	2.9	1.0	.4

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION B - AREA 9

Irrigable soils comprise 22% of the Area's 2928 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 30 % of the agricultural water comes from ground water and 70 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	20.8	8.3	62.9	2.3	10.9
2000	14.4	8.3	27.3	3.8	17.5
2020	14.4	3.7	7.9	5.3	26.1

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	17.6	4.1	.1	11.8	9.8	.1					
NATIONAL EFFICIENCY												
	1980	5.3	6.8	.4	18.9	15.2	.4	15.4	1.7	3.4	1.1	1.2
	2000	-7.1	6.6	1.8	-9.5	15.3	1.8	13.8	1.4	2.7	.9	1.0
	2020	0	8.6	3.0	0	19.7	3.0	18.2	1.9	3.6	1.2	1.1
REGIONAL DEVELOPMENT												
	1980	8.9	6.8	.8	23.9	15.2	.8	16.8	1.9	3.6	1.2	1.3
	2000	1.1	6.6	2.1	1.9	15.3	2.1	16.5	1.9	3.2	1.0	1.1
	2020	-4.6	8.6	2.3	-5.5	19.7	2.3	17.9	1.9	3.6	1.2	1.1
ENVIRONMENTAL QUALITY												
	1980	8.9	6.8	2.2	23.9	15.2	2.2	17.2	2.0	3.7	1.2	1.4
	2000	1.1	6.6	1.5	1.9	15.3	1.5	16.4	1.9	3.2	1.0	1.1
	2020	0	8.6	1.5	0	19.7	1.5	17.7	1.8	3.8	1.2	1.1

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION B - AREA 10

Irrigable soils comprise 22% of the Area's 2916 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25 % of the agricultural water comes from ground water and 75 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	7.0	9.0	119.0	2.6	7.7
2000	3.5	9.3	52.2	4.3	12.0
2020	1.8	12.7	16.5	6.0	17.6

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	5.1	2.2	.2	2.8	5.5	.2					
NATIONAL EFFICIENCY												
	1980	2.6	5.0	.3	5.6	11.0	.3	10.9	1.2	2.3	.8	.5
	2000	-3.8	4.3	2.0	-4.1	10.0	2.0	9.2	1.0	1.8	.6	.3
	2020	-1.9	5.6	3.5	-2.1	12.9	3.5	12.3	1.3	2.4	.8	.5
REGIONAL DEVELOPMENT												
	1980	6.7	5.0	.8	10.7	11.0	.8	12.4	1.4	2.6	.9	.7
	2000	5.9	4.3	2.4	7.9	10.0	2.4	12.5	1.6	2.4	.9	.7
	2020	-1.9	5.6	2.6	-2.1	12.9	2.6	12.0	1.3	2.4	.8	.5
ENVIRONMENTAL QUALITY												
	1980	6.7	5.0	2.4	10.7	11.0	2.4	13.0	1.5	2.7	.9	.7
	2000	5.9	4.3	1.6	7.9	10.0	1.6	12.3	1.5	2.4	.8	.7
	2020	2.4	5.6	1.8	3.0	12.9	1.8	13.2	1.5	2.6	.9	.6

NOTE: The values shown in the table are incremental, Price Base 1966.

SUBREGION C - AREA 11

Irrigable soils comprise 15% of the Area's 7616 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 20 % of the agricultural water comes from ground water and 80 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	5.4	62.0	775.6	.8	.2
2000	1.8	66.0	525.2	1.3	.8
2020	1.8	98.0	321.2	1.8	1.8

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	1.0	.4	0	.6	1.0	0					
NATIONAL EFFICIENCY												
	1980	.5	2.5	.2	1.4	5.6	.2	5.2	.5	1.0	.3	.2
	2000	.5	1.7	.6	.6	4.0	.6	3.8	.4	.8	.3	.1
	2020	0	2.2	1.0	0	5.1	1.0	4.7	.5	.9	.3	.2
REGIONAL DEVELOPMENT												
	1980	48.2	2.5	.3	65.8	5.6	.3	20.8	3.4	3.9	1.6	1.8
	2000	112.6	1.7	.8	151.7	4.0	.8	40.2	7.1	7.5	3.3	4.0
	2020	0	2.2	.7	0	5.1	.7	4.6	.5	.9	.3	.1
ENVIRONMENTAL QUALITY												
	1980	48.2	2.5	.8	65.8	5.6	.8	20.9	3.4	4.0	1.6	1.8
	2000	112.6	1.7	.6	151.7	4.0	.6	40.2	7.1	7.5	3.3	4.0
	2020	32.0	2.2	.4	41.3	5.1	.4	14.9	2.4	2.8	1.2	1.2

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION C - AREA 12

Irrigable soils comprise 36% of the Area's 8554 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 25 % of the agricultural water comes from ground water and 75 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	43.3	95.5	839.2	1.6	8.2
2000	28.3	97.3	546.4	2.7	13.2
2020	28.3	138.0	297.7	3.8	19.6

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ % Land
	1966	17.3	2.1	.1	9.4	5.3	.1					
NATIONAL EFFICIENCY												
	1980	8.0	6.1	.2	8.8	12.6	.2	14.9	1.7	3.4	1.1	.4
	2000	5.8	5.0	1.3	6.3	11.5	1.3	12.3	1.4	2.8	.9	.4
	2020	0	6.4	2.2	0	14.7	2.2	13.5	1.4	2.7	.9	.3
REGIONAL DEVELOPMENT												
	1980	64.8	6.1	.5	82.8	12.6	.5	33.4	5.1	6.8	2.6	1.1
	2000	140.3	5.0	1.6	181.0	11.5	1.6	56.1	9.5	10.9	4.6	1.9
	2020	0	6.4	1.6	0	14.7	1.6	13.3	1.4	2.6	.9	.3
ENVIRONMENTAL QUALITY												
	1980	64.8	6.1	1.5	82.8	12.6	1.5	33.7	5.2	6.9	2.7	1.1
	2000	140.3	5.0	1.1	181.0	11.5	1.1	56.0	9.5	10.8	4.5	1.9
	2020	61.3	6.4	1.1	74.1	14.7	1.1	33.1	5.0	6.3	2.5	1.0

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION C - AREA 13

Irrigable soils comprise 26% of the Area's 1217 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 100 % of the agricultural water comes from ground water and 0 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	13.6	.4	2.0	.5	11.7
2000	-	-	-	.9	18.9
2020	-	-	-	1.2	28.5

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres) Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet) Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million) One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	37.9	6.1	0	18.6	14.2	0					
NATIONAL EFFICIENCY												
	1980	-22.9	5.6	.1	-3.8	12.8	.1	11.2	1.1	2.2	.7	2.2
	2000	-15.0	7.2	.4	-14.8	16.5	.4	14.5	1.5	2.9	1.0	3.0
	2020	0	9.6	.7	0	21.2	.7	19.4	2.0	3.9	1.3	4.5
REGIONAL DEVELOPMENT												
	1980	-22.7	5.6	.2	-3.5	12.8	.2	11.2	1.1	2.2	.7	2.2
	2000	-15.2	7.2	.4	-15.1	16.5	.4	14.5	1.5	2.9	1.0	3.0
	2020	0	9.6	.6	0	21.2	.6	19.3	2.0	3.9	1.3	4.4
ENVIRONMENTAL QUALITY												
	1980	-22.7	5.6	.3	-3.5	12.8	.3	11.3	1.1	2.2	.7	2.2
	2000	-15.2	7.2	.5	-15.1	16.5	.5	14.5	1.5	2.9	1.0	3.0
	2020	0	9.6	.4	0	21.2	.4	19.3	1.9	3.8	1.2	4.4

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION D - AREA 14

Irrigable soils comprise 31% of the Area's 1520 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 55 % of the agricultural water comes from ground water and 45 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	9.1	7.9	93.0	1.1	7.2
2000	5.4	7.4	39.2	1.9	11.7
2020	2.4	9.2	12.4	2.6	17.3

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	8.8	3.2	.1	4.2	7.7	.1					
NATIONAL EFFICIENCY												
	1980	1.2	4.0	.1	5.2	9.2	.1	8.4	.9	1.8	.6	1.1
	2000	-4.0	4.5	.9	-3.7	10.3	.9	9.3	1.0	1.8	.6	.8
	2020	-3.3	5.6	1.5	-2.3	13.2	1.5	11.7	1.2	2.3	.8	1.0
REGIONAL DEVELOPMENT												
	1980	4.6	4.0	.4	9.4	9.2	.4	9.6	1.1	2.0	.7	1.4
	2000	3.4	4.5	1.0	5.5	10.3	1.0	11.7	1.4	2.1	.7	1.4
	2020	-3.3	5.6	1.1	-2.3	13.2	1.1	11.6	1.2	2.3	.8	1.0
ENVIRONMENTAL QUALITY												
	1980	4.6	4.0	1.1	9.4	9.2	1.1	9.8	1.1	2.0	.7	1.4
	2000	3.4	4.5	.7	5.5	10.3	.7	11.6	1.2	2.0	.7	1.4
	2020	-.5	5.6	.7	1.2*	13.2	.7	12.3	1.3	2.4	.8	1.2

NOTE: The values shown in the table are incremental. Price Base 1966.
* Positive value is due to shift in type of crop irrigated.

SUBREGION D - AREA 15

Irrigable soils comprise 46% of the Area's 8169 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 35 % of the agricultural water comes from ground water and 65 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	110.4	225.6	1018.0	10.1	17.4
2000	125.8	197.0	530.2	16.8	28.0
2020	94.5	230.5	304.0	23.4	41.6

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	83.8	6.2	.6	43.2	15.0	.6					
NATIONAL EFFICIENCY												
	1980	33.2	11.2	1.4	77.8	25.0	1.4	33.6	4.3	8.5	2.8	1.7
	2000	20.8	10.6	8.0	21.5	24.3	8.0	30.6	3.8	7.2	2.4	1.6
	2020	-33.8	13.6	13.4	-34.9	31.3	13.4	31.6	3.5	6.2	2.1	1.0
REGIONAL DEVELOPMENT												
	1980	124.7	11.2	3.4	189.5	25.0	3.4	64.0	9.9	14.2	5.3	2.8
	2000	217.3	10.6	9.4	270.0	24.3	9.4	94.9	15.7	19.1	7.7	4.0
	2020	-33.8	13.6	10.0	-34.9	31.3	10.0	30.4	3.3	6.0	2.0	1.0
ENVIRONMENTAL QUALITY												
	1980	124.7	11.2	9.4	189.5	25.0	9.4	66.0	10.3	14.5	5.5	2.9
	2000	217.3	10.6	6.7	270.0	24.3	6.7	94.0	15.6	18.9	7.7	4.0
	2020	38.1	13.6	6.7	63.5	31.3	6.7	52.7	7.4	10.2	3.9	1.8

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION D - AREA 16

Irrigable soils comprise 40% of the Area's 1532 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 55% of the agricultural water comes from ground water and 45% from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	32.6	7.6	58.8	1.8	2.5
2000	32.6	10.8	41.6	3.0	4.0
2020	32.6	10.8	26.6	4.1	5.9

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	22.8	1.2	.1	14.2	2.9	.1					
NATIONAL EFFICIENCY												
	1980	13.1	1.3	.3	30.5	2.8	.3	7.0	1.1	2.1	.7	2.5
	2000	0	1.5	.8	0	3.5	.8	3.3	.3	.6	.2	1.7
	2020	0	1.9	2.9	0	4.4	2.9	4.7	.5	.9	.3	1.9
REGIONAL DEVELOPMENT												
	1980	20.6	1.3	.6	45.4	2.8	.6	9.5	1.5	2.6	.9	3.0
	2000	18.9	1.5	1.7	35.5	3.5	1.7	9.7	1.5	1.8	.7	3.0
	2020	0	1.9	1.7	0	4.4	1.7	4.4	.5	.9	.3	1.8
ENVIRONMENTAL QUALITY												
	1980	20.6	1.3	1.7	45.4	2.8	1.7	9.8	1.6	2.6	.9	3.1
	2000	18.9	1.5	1.2	35.5	3.5	1.2	9.5	1.5	1.8	.7	3.0
	2020	0	1.9	1.1	0	4.4	1.1	4.2	.4	.8	.3	1.8

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION E - AREA 17

Irrigable soils comprise 35% of the Area's 17607 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 30 % of the agricultural water comes from ground water and 70 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	54.3	606.3	2646.4	3.9	9.8
2000	33.5	548.8	1993.7	6.5	15.7
2020	40.9	700.2	1277.9	9.1	23.4

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	13.7	2.6	.2	10.4	6.4	.2					
NATIONAL EFFICIENCY												
	1980	15.6	7.2	.6	34.4	16.1	.6	19.7	2.4	4.8	1.6	.2
	2000	7.6	5.9	3.1	11.7	13.7	3.1	15.3	1.8	3.4	1.1	.2
	2020	8.1	7.7	5.2	12.4	17.6	5.2	19.7	2.3	4.4	1.4	.2
REGIONAL DEVELOPMENT												
	1980	294.6	7.2	1.4	505.7	16.1	1.4	110.6	19.2	21.6	9.1	1.8
	2000	630.1	5.9	3.6	1087.8	13.7	3.6	217.8	39.2	40.8	18.0	3.7
	2020	8.1	7.7	3.9	12.4	17.6	3.9	19.3	2.3	4.3	1.4	.2
ENVIRONMENTAL QUALITY												
	1980	294.6	7.2	2.7	505.7	16.1	2.7	111.0	19.3	21.6	9.1	1.8
	2000	630.1	5.9	3.6	1087.8	13.7	3.6	217.8	39.2	40.8	18.0	3.7
	2020	297.8	7.7	2.6	525.4	17.6	3.6	113.0	19.6	21.6	9.2	1.8

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION E - AREA 18

Irrigable soils comprise 63% of the Area's 5213 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 30 % of the agricultural water comes from ground water and 70 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	90.4	418.4	776.2	3.5	4.6
2000	81.6	442.5	473.9	5.8	7.5
2020	77.1	498.7	204.2	8.1	11.1

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	29.9	1.8	.2	13.6	4.2	.2					
NATIONAL EFFICIENCY												
	1980	28.8	2.8	.5	39.9	6.5	.5	15.1	2.3	4.6	1.5	1.2
	2000	31.1	2.9	2.8	28.4	6.5	2.8	16.8	2.6	5.1	1.7	1.3
	2020	0	3.6	4.6	0	8.3	4.6	8.7	1.0	1.7	.6	.8
REGIONAL DEVELOPMENT												
	1980	163.0	2.8	1.2	204.9	6.5	1.2	59.0	10.4	12.7	5.1	3.8
	2000	367.4	2.9	3.2	440.4	6.5	3.2	126.2	22.8	25.3	10.8	7.8
	2020	0	3.6	3.5	0	8.3	3.5	8.3	.9	1.6	.5	.7
ENVIRONMENTAL QUALITY												
	1980	163.0	2.8	3.3	204.9	6.5	3.3	59.6	10.5	12.8	5.2	3.8
	2000	367.4	2.9	2.3	440.4	6.5	2.3	126.0	22.8	25.2	10.7	7.8
	2020	61.8	3.6	2.3	77.0	8.3	2.3	28.0	4.6	5.3	2.2	1.9

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION F - AREA 19

Irrigable soils comprise 42% of the Area's 9389 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 20 % of the agricultural water comes from ground water and 80 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	54.7	392.3	1228.0	3.9	8.6
2000	42.5	363.4	899.1	6.6	13.9
2020	37.4	457.0	533.6	9.0	20.6

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	13.5	2.6	0	7.9	6.3	0					
NATIONAL EFFICIENCY												
	1980	19.3	6.0	1.0	30.8	13.7	1.0	18.6	2.4	4.8	1.6	.4
	2000	13.9	5.3	3.0	16.4	12.0	3.0	16.1	2.1	4.0	1.3	.4
	2020	-5.6	6.7	5.0	-6.6	15.0	5.0	15.0	1.6	3.0	1.0	.2
REGIONAL DEVELOPMENT												
	1980	172.3	6.0	2.0	220.4	13.7	2.0	68.6	11.6	14.0	5.7	2.1
	2000	352.3	5.3	3.0	443.9	12.0	3.0	126.1	22.4	24.3	10.5	4.0
	2020	-5.6	6.7	4.0	-6.6	15.0	4.0	14.7	1.6	2.9	1.0	.2
ENVIRONMENTAL QUALITY												
	1980	172.3	6.0	4.0	220.4	13.7	4.0	69.3	11.8	14.1	5.8	2.1
	2000	352.3	5.3	3.0	443.9	12.0	3.0	126.1	22.4	24.3	10.5	4.0
	2020	130.6	6.7	2.0	168.4	15.0	2.0	56.5	9.3	11.0	4.5	1.6

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION F - AREA 20

Irrigable soils comprise 51% of the Area's 3840 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 20% of the agricultural water comes from ground water and 80% from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	5.9	134.1	334.0	1.3	.8
2000	3.0	126.2	221.8	2.2	1.3
2020	2.0	148.0	108.0	3.0	1.9

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres): Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet): Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ (% Land)
	1966	1.9	.2	0	1.1	.4	0					
NATIONAL EFFICIENCY												
	1980	.3	.6	0	1.3	1.6	0	1.3	.2	.3	.1	.1
	2000	0	.5	1.0	0	1.0	1.0	1.3	.2	.3	.1	.1
	2020	0	.6	2.0	0	1.0	2.0	1.8	.2	.4	.1	.1
REGIONAL DEVELOPMENT												
	1980	44.0	.6	1.0	50.8	1.6	1.0	15.8	2.8	3.0	1.3	1.2
	2000	97.0	.5	1.0	108.7	1.0	1.0	32.8	6.0	6.1	2.7	2.6
	2020	0	.6	1.0	0	1.0	1.0	1.5	.2	.3	.1	.1
ENVIRONMENTAL QUALITY												
	1980	44.0	.6	1.0	50.8	1.6	1.0	15.8	2.8	3.0	1.3	1.2
	2000	97.0	.5	1.0	108.7	1.0	1.0	32.8	6.0	6.1	2.7	2.6
	2020	27.2	.6	1.0	30.5	1.0	1.0	10.4	1.8	1.9	.8	.8

NOTE: The values shown in the table are incremental. Price Base 1966.

SUBREGION F - AREA 21

Irrigable soils comprise 41% of the Area's 6784 thousand acres.

Recommended devices are wells, pump and pipe (instream) and impoundments.

About 20 % of the agricultural water comes from ground water and 80 % from surface water sources. The predominant source of nonagricultural water is from ground water.

Acreage Considered for Irrigation
(Based on historical trends)

	Cropland			Nonagricultural	
	Specialized Crops	Field Corn	Other Cropland	Indstrl & Instl	Golf Courses
	(1000 Acres)				
1980	6.7	133.8	450.5	2.8	4.1
2000	5.7	120.8	291.5	4.6	6.5
2020	5.4	140.2	153.4	7.0	9.7

Emphasized Objective	Time Frame: Year	Irrigation Demands: Land (1000 Acres) Crop-land	Golf Courses	Indstrl & Instl	Water (1000 Acre Feet) Crop-land	Golf Courses	Indstrl & Instl	Cost ($ million): One Time	Avg Ann	Benefit Toward Each Objective: NE (Avg Ann $ Mill.)	RD	EQ % Land
	1966	4.3	1.0	0	2.4	2.4	0					
NATIONAL EFFICIENCY												
	1980	1.6	3.1	1.0	4.0	6.6	1.0	7.0	.8	1.5	.5	.2
	2000	.4	2.4	2.0	.4	6.0	2.0	5.6	.6	1.1	.4	.1
	2020	-.3	3.2	4.0	-.3	7.0	4.0	7.7	.9	1.5	.5	.2
REGIONAL DEVELOPMENT												
	1980	49.3	3.1	1.0	56.8	6.6	1.0	22.5	3.6	4.4	1.8	.9
	2000	103.4	2.4	3.0	113.2	6.0	3.0	39.4	6.9	7.4	3.2	1.7
	2020	-.3	3.2	3.0	-.3	7.0	3.0	7.4	.8	1.5	.5	.2
ENVIRONMENTAL QUALITY												
	1980	49.3	3.1	3.0	56.8	6.6	3.0	23.2	3.8	4.8	1.9	.9
	2000	103.4	2.4	2.0	113.2	6.0	2.0	39.1	6.8	7.3	3.2	1.7
	2020	33.8	3.2	2.0	35.2	7.0	2.0	18.0	2.8	3.4	1.4	.7

NOTE: The values shown in the table are incremental. Price Base 1966.